TABLES FOR QUALITATIVE CHEMICAL ANALYSIS

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TABLES

FOR

QUALITATIVE CHEMICAL ANALYSIS

ARRANGED FOR THE USE OF STUDENTS

BY

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SECOND EDITION

London

MACMILLAN AND CO., LIMITED

1904

INTRODUCTION.

In these tables, primarily prepared for the use of my own students, I have made an attempt to combine some of the advantages of Quantitative methods with the processes of Qualitative Analysis. It is assumed that the student using these tables has been through a preliminary course of practical instruction, including such matters as glass working, the use of the blowpipe, an instrument far too much neglected nowadays, the preparation of the gases and of certain salts, etc.

The experiments upon the preparation of gases, salts, etc., should also be carried out upon Quantitative methods, *i.e.*, the quantities of the materials necessary for their preparation should be calculated and weighed out or measured by the student himself.

In the case of gases, he should also be required to measure the capacity of the gas jars intended to be filled and to correct their contents for temperature and pressure.

This part of the experimental work will thereby afford far better training, be more instructive and more interesting to the beginner than the usual routine arithmetical questions upon the preparation of given volumes of gases and the correction for temperature and pressure.

The educational value of Qualitative Analysis.—Of late it has been usual to condemn instruction in Qualitative Analysis, and to allege that it is a waste of time. This may be true if the student is allowed to go on mechanically testing mixture after mixture and is not required to give evidence that he understands what he is doing; to this end he should be frequently questioned as to the reasons for making any given experiment, and the chemical reactions it is intended to bring about.

If the student be required to do his qualitative work intelligently, the time given to it is well spent; there is probably more scientific training and discipline involved in it than in ordinary Quantitative Analysis, and if properly taught it is of great educational value.

The preliminary tests applied to complex mixtures are especially useful in training the observing and reasoning powers, on account of the way in which reactions are modified or interfered with when several substances are present.

It is not possible for everyone who requires some knowledge of practical chemistry to devote time to such matters as the verification of the laws of

combination, the preparation and the purification of materials or to undertake an original research, but many, *e.g.*, medical students, require to have some knowledge of Qualitative Analysis; chemical and mining students need a larger and better knowledge, and it is desirable that they should be taught this in an instructive manner and not as mere test-tubing.

It is, of course, not necessary for every student to work through the reactions for all the substances given in these tables; typical ones can be selected according to circumstances, *e.g.* the medical student need not necessarily work through the reactions of rare earths.

Theory of Qualitative Analysis.—It is assumed that the student will be taught the principles of analysis and how to use these tables, and that he will not be left to struggle through them unaided; it is for this reason and because the book is intended for bench use that equations and the usual more or less lengthy explanations are omitted.

The directions are made as brief as possible, for students when engaged in practical work have usually neither the time nor the inclination to wade through more or less lengthy descriptions of the methods of procedure.

In this laboratory the principal explanations are given in the form of lecturettes and demonstrations of fifteen or twenty minutes before the practical exercises; the class also meets once a week for one hour's tutorial instruction in the theory of qualitative analysis, chemical equations, calculations and similar matters, and there is a written examination upon the work at the end of the term, as well as practical and theoretical examinations at the end of the year.

Weighing and Measuring.—By requiring the student to work throughout with weighed or measured quantities, it is necessary that he should be shown, unless he is already familiar with them, how to use the balance, burette, measuring flasks and pipettes; the small amount of extra time necessary for this will, however, be well spent.

The quantity of substance to be examined can either be weighed out separately by each student, or students can take it in turns to weigh out and divide the portions for a group of students.

The balance used need not be an expensive one, very good chemical balances, weighing to a milligram. can now be obtained for less than 30/-; if the balance available is not sufficiently sensitive for the smaller weights, larger quantities can be weighed out, placed on glass or glazed paper and divided by a spatula into approximately equal parts, just as powders are sometimes divided by pharmacists; although this would not be quite so satisfactory, it would be a great improvement upon the usual method of shaking an indefinite quantity out of a bottle.

In applying the colour tests for alkaloids, a weighed quantity, say a milligram, should be divided by a spatula into the requisite number of approximately equal portions, as it is quite unnecessary to weigh the fractions of a mgm.

Although a mgm. may be thought to be a small amount to be divided into five or even more portions, yet as the alkaloids are of comparatively low density there is no practical difficulty in obtaining the reactions with such quantities; in poisoning cases the amount of alkaloid to be sought for is usually small, it is therefore well for the student to acquire skill in working with small quantities.

The amounts of material and reagents recommended have been carefully tested and proved to be ample for the purpose, and in some instances even smaller quantities than those mentioned would be sufficient.

The amounts prescribed are not given in proportion to the equivalent or molecular weights of the substances, because the difference between them and those recommended would not, as a rule, be appreciable.

The quantities to be used are given to promote accuracy of work, to save time, and to prevent waste of chemicals; usually an excessive quantity of the substance to be tested is used and then "drowned" in acids and reagents, which means great waste of material and a greater and more deplorable waste of time in filtering large volumes of solution and in washing bulky and unwieldy precipitates. Further, by causing students to weigh and measure out the materials, they will acquire during their qualitative work a knowledge of the use of the balance and of volumetric apparatus which will be a useful introduction to quantitative determinations.

Graduated Test Tubes.—For simple tests, small test tubes of ½ or ⅝ inch diameter are much better than the larger sizes, for their contents can be boiled and otherwise treated so much more quickly.

It is as well to have these graduated into c.c.; the student should do this for himself by running in water from a burette and marking the c.c. by gummed paper bands, with paint, or by hydrofluoric acid ink, etc.; one burette will be sufficient for several students.

Equivalent Solutions. The acids and solutions used should be "equivalent" ones, so that even the ordinary precipitation and other tests can with the use of graduated test tubes be carried out in a more or less quantitative manner. A table of Equivalent Solutions is given on page 115.

When an "excess" of a reagent is to be added, the beginner will be able to carry out the operation much less clumsily than he usually does with ungraduated test tubes.

Instead of being told to add "a few drops," which to the ordinary beginner means anything from 5 or 6 drops to several c.c., he should be required to add a definite number of drops carefully counted.

It is usually the best plan to deliver the drops from the end of a glass rod, although in careless hands this may lead to the reagents being contaminated, from the unrinsed rods being dipped into other bottles. Dropping-bottles and bottles with pipette stoppers are very useful for certain reagents, but they cannot well be used for all of them.

Mixtures.—The mixtures for analysis should, as far as possible, be made up in terms of the molecular weights of the constituents, and in proportions according to the difficulty of detecting them and not haphazard, as is too often the case.

After a little experience with the usual artificial laboratory mixtures, minerals and other natural mixtures should be given wherever possible, as they usually present greater difficulties and are of more educational value.

Preliminary Tests.—Most common substances can be detected by the preliminary tests, and a student should be required to learn to do so as far as possible, he then, if provided with a blowpipe, a candle, a few accessories and reagents, is almost independent of a laboratory, *i.e.*, as far as ordinary minerals and common substances are concerned; the power to work with few and simple materials is an immense advantage to the explorer and miner.

If the student finds a substance by the wet processes, which he has failed to detect by the preliminary tests, he should be required to repeat the preliminary tests until he does find it, *i.e.*, if it is possible to do so, if impossible he should be required to state in his note book the probable reasons why it cannot be so detected, especially if there be anything present which interferes with or masks the usual reactions of the substance in question.

Blowpipe Tests. For the blowpipe tests, a portion of the substance not larger than a pin's head is usually ample; beginners often fail to get the proper results because they use too much of the substance, they often use such excessive quantities as to almost need a crucible and a furnace instead of a mouth blowpipe. Students should be carefully shown how to make a suitable cavity in charcoal for blowpipe experiments, how to make a proper platinum wire ring (not an irregular loop) for borax beads, how to mix fluxes, and other similar operations, and not be left to do them in the usual slovenly way.

Note Books.—Students should be required to enter the date and hour they commence and finish a given piece of work, and to enter up a table of

contents at the beginning of the note book, so that the progress and range of their work can be seen and kept in view both by the teacher and student. The entries should as far as possible be initialled by the instructor from day to day and not at intervals of a week or so.

I am only too well aware of the inherent defects in these, in common with other similar analytical tables, and mistakes may also have crept in unawares, but I hope that teachers of chemistry into whose hands they come will not only give the quantitative methods described a fair test, but improve upon them.

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The University of Sydney.
December, 1903

ERRATA.

Page 15, line 25, for $Fe_3''(Fe'''Cy_6)_3$ read $Fe_3''(Fe'''Cy_6)_2$.
,, 18, lines 2 and 4 from foot, for $K_3Co(NO_2)_3$ read $K_3Co(NO_2)_6$.
,, 18, last line, for $Ni(OH)_3$ read $Ni(OH)_2$.
,, 30, line 8 from foot, for ZrS_2O_3 read $Th(OH)_4$ and S.
,, 30, line 12, for ZrS_2O_3 read $Zr(OH)_4$ and S.
,, 30, line 6 from foot, for Titanum read Titanium.
,, 37, line 8 from foot, for $CuSO_4$ read Cu_2SO_4.
,, 110, line 9, for ·1 gm. read 1 gm.

REACTIONS OF THE METALS.

GROUP I.—SILVER, LEAD AND MERCURY.

Silver. Ag, 107·12.

DRY TESTS.—1. **Blowpipe.** Heat about ·01 gm. $AgNO_3$ on charcoal with Na_2CO_3 : hard white malleable metallic beads. Diss. beads in dil. HNO_3, add NaCl sol. : white AgCl.

2. **Match test.** Use about ·01 gm. $AgNO_3$: Ag beads.

WET TESTS.—Diss. ·1 gm. of $AgNO_3$ in 10 c.c. aq. and use 1 c.c. for each test.

HCl : white curdy ppt. of AgCl, insol. in dil. acids, soluble in NH_4OH, KCN, $Na_2S_2O_3$, also in strong HCl, NaCl sol. etc. The AgCl darkens on exposure to light.

SH_2 : black Ag_2S, insol. in NH_4SH.

NH_4OH : grey AgOH. (Note. Very sol. in excess. Apply the NH_4OH from the end of a thin glass rod to the side of the test tube just above the $AgNO_3$ sol. and let the NH_4OH trickle down to the $AgNO_3$ sol.)

NaOH : grey brown AgOH, insol. in excess.

Na_2CO_3 : white Ag_2CO_3, insol. in excess.

KI : pale yellow AgI, insol. in dil. HNO_3 and almost insol. in NH_4OH.

KBr : yellowish AgBr, insol. in dil. HNO_3, difficultly sol. in NH_4OH, readily in KCy, $Na_2S_2O_3$, and KI.

KCy : white curdy AgCy, readily sol. in an excess, in NH_4OH, and in $Na_2S_2O_8$ but insol. in dil. HNO_3; on ignition : metallic silver.

K_2CrO_4 : dark red Ag_2CrO_4.

Copper foil : ppt. of grey metallic Ag ; rub with glass rod : metallic lustre.

Lead. Pb, 205·35.

DRY TESTS—1. **Blowpipe.** Heat about ·01 gm. Pb2NO_3 on char. in the *reducing* flame : soft, greyish metallic beads which mark paper. In the *oxidising* flame an incrustation is formed, reddish brown when hot, yellow when cold.

2. **Match test.** Use about ·02 gm. Pb2NO_3 : Pb beads.

3. **Film test** : black.

WET TESTS.—Diss. 0·2 gm. of lead acetate, in 7 c.c. aq. (if cloudy add one drop of acetic acid).

HCl : white crystalline $PbCl_2$, insol. in NH_4OH, sol. in hot aq., redeposited on cooling. Filter and pass SH_2 through the cold sol. : a black ppt. of PbS which shows that $PbCl_2$ is somewhat soluble in the cold, or add KI sol. : yellow PbI_2.

SH_2 in the presence of HCl : black PbS, but if too much HCl be present a reddish ppt. of $PbS,PbCl_2$ comes down.

H_2SO_4 : white $PbSO_4$, soluble in ammonium acetate, in am. tartrate, in excess of NH_4OH and in $Na_2S_2O_3$.

NH_4OH : white ppt. (basic salt), which crystallizes out on cooling, insol. in excess.

NaOH : white PbO_2H_2, sol. in excess.

KI : yellow ppt. of PbI_2 sol. in excess and in hot aq.

K_2CrO_4 : yellow $PbCrO_4$, sol. in HNO_3 and in NaOH.

Mercury. Hg, 198·5.

DRY TESTS.—1. **Blowpipe.** On charcoal, volatilizes.

2. **Ignition tube.** (*a*) Heated in a dry tube, salts of mercury yield a sublimate. (*b*) Heated in a tube with soda-lime or char. powder and Na_2CO_3 : metallic globules or mirror, insoluble in HCl, soluble in hot HNO_3 and in H_2SO_4.

3. **Film test** : (*a*) Metallic mirror; (*b*) with **SH_2** : black.

	MERCUROUS SALTS.	MERCURIC SALTS.
WET TESTS.	—Diss. ·2 gm. $HgNO_3$ in 10 c.c. aq. and a few drops dil. HNO_3.	—Diss. ·2 gm. $HgCl_2$ in 10 c.c. aq.
HCl	: white ppt. of HgCl, blackened by NH_4OH.	: no ppt.
SH_2	: black HgS mixed with Hg, soluble in aq. regia, insol. in NH_4SH.	: white, yellow and red mixtures of $HgCl_2$ and HgS, finally black HgS.
NH_4OH	: black ppt.*	: white ppt. of ($NH_2.Hg''Cl$).
NaOH	: dark grey ppt. Hg_2O.	: yellow HgO.
Na_2CO_3	: white ppt. ; darkens	: brown ppt.
KI	: green HgI, sol. in excess of KI.	: yellow changing to red HgI_2, sol. in excess of KI and of $HgCl_2$.
$K_2Cr_2O_7$	: red ppt.	: no ppt. but a yellow ppt. with K_2CrO_4.
$SnCl_2$	: white HgCl, on warming : grey metallic Hg.	: white ppt. of HgCl, grey with an excess of $SnCl_2$.

* Probably a mixture of mercuric am. nitrate and free Hg.

Acidulate slightly with HCl and immerse a strip of bright copper foil: grey deposit of metallic Hg, from both the $HgNO_3$ and $HgCl_2$ sols., rub to collect into globules and to show metallic lustre.

GROUP IIA.—MERCURY, LEAD, BISMUTH, COPPER AND CADMIUM.

Bismuth. Bi, 206·9.

DRY TESTS.—1. **Blowpipe.** Heat ·02 gm. Bi_2O_3 on charcoal in inner flame with Na_2CO_3 and KCy : brittle reddish metallic beads and orange incrustation, but yellow on cooling.

2. **Ignition tube.** Heated in tube, Bi salts decompose and leave Bi_2O_3, orange when hot, yellow when cold.

3. **Match test.** Use about ·01 gm. Bi_2O_3 : Bi beads.

WET TESTS.—Diss. ·1 gm. $Bi(NO_3)_3$ in 7 c.c. aq., or ·2 gm. Bi_2O_3 in 5 c.c. dil. HCl, then dilute with aq. to 7 c.c.

HCl : no ppt., but on diluting very largely with aq., white BiOCl comes down, insol. in KOH and in $KHC_4H_4O_6$ (Hyd. pot. tartrate).

SH_2 : dark brown ppt. of Bi_2S_3, insol. in NaOH, sol. in HNO_3.

NH_4OH : white Bi $(OH)_3$, insol. in excess.

NaOH : white $Bi(OH)_3$, insol. in excess.

KI : (0·1% soln.) : brown BiI_3, very sol. in excess.

KCy : white $Bi(Cy)_3$, insol. in excess.

$K_2Cr_2O_7$: yellow $Bi_2(CrO_4)_3$.

Copper. Cu, 63·1.

DRY TESTS.—1. **Blowpipe.** Mix about ·02 gm. CuO with Na_2CO_3 and KCy, heat on charcoal in reducing flame : red malleable metallic particles.

2. **Match test** : Cu beads.

3. **Borax bead** : green, hot; blue, cold; red in reducing flame.

4. **Flame test** : flame, coloured green; halogen compounds of Cu, *e.g.*, $CuCl_2$, give a vivid blue.

A.—CUPROUS COMPOUNDS.

WET TESTS.—Dissolve 0·1 gm. Cu_2Cl_2 in 2 c.c. HCl.

H_2O : white Cu_2Cl_2, changes to green $CuCl_2$, which is soluble.

KOH : yellow ppt. of CuOH, which absorbs O and becomes black $Cu(OH)_2$.

B—CUPRIC COMPOUNDS.

WET TESTS.—Diss. 0·2 gm. $CuSO_4$ in 10 c.c. aq., use 1 c.c. for each test.

HCl : no ppt.

SH_2 : black CuS, nearly insol. in NH_4SH and NaOH, sol. in strong HNO_3

NH_4OH : pale blue ppt. of basic salt, $CuSO_4.Cu(OH)_2$, sol. in excess to a deep blue sol.

NaOH : CuO_2H_2, cupric hydroxide, turns black on boiling : CuO, but if substances like grape sugar, tartaric acid, tartrates, urea, are present, a deep blue solution forms, from which on boiling red Cu_2O is precipitated.

Na_2CO_3 : greenish blue basic carbonate, on boiling : black CuO or $3CuO,H_2O$.

$K_4Fe(Cy)_6$: chocolate-coloured ppt. of cupric ferrocyanide, Cu_2FeCy_6.

KCy : greenish $Cu(Cy)_2$, sol. in excess. [NOTE.—SH_2 does not ppt. Cu from this soln. See Cd.]

Metallic Zn or Fe ppts. copper from solution as a reddish powder, rub : bright copper particles.

Cadmium. Cd, 111·6.

DRY TESTS.—1. **Blowpipe.** Mix about ·02 gm. $CdSO_4$ with Na_2CO_3 and KCy, and heat on charcoal in inner flame : reddish brown incrustation of CdO.

2. **Film test** : black, yellow with SH_2 sol.

WET TESTS.—Diss. ·1 gm. of $CdSO_4$ in 5 c.c. of aq.

SH_2 and 2 drops of HCl : yellow CdS, insol. in NaOH, NH_4SH, KCy, and in $(NH_4)_2CO_3$; sol. in hot dil. HCl, HNO_3 and H_2SO_4.

NH_4OH : white ppt. of $Cd(OH)_2$ sol. in excess.

NaOH : white ppt. of $Cd(OH)_2$ insol. in excess.

NH_4SH : yellow ppt. of CdS.

KCy : white $CdCy_2$, sol. in excess; SH_2 ppts. CdS from this sol. (See Copper, p. 11.)

GROUP IIB.—ARSENIC, ANTIMONY AND TIN.

Arsenic. As, 74·4

DRY TESTS.—1. **Blowpipe.** Mix with Na_2CO_3 and heat on charcoal : white incrustation of As_2O_3 and garlic odour.

2. **Ignition tube.** (*a*) Heated in a roasting tube As and arsenical compounds give a sublimate of As_2O_3; (*b*) mixed with charcoal powder and soda lime (or with charcoal, dry Na_2CO_3 and KCy) and (*c*) heated in a bulb tube, they yield a mirror and emit a garlic odour.

Use ·01 gm. of Na_3AsO_3 for each of the above tests.

NOTE.—Arsenical fumes are *poisonous*, therefore smell cautiously by wafting the fumes to the nose by the hand.

3. **Film test.** Metallic, with SH_2 sol. : yellow.

ARSENIOUS COMPOUNDS.

WET TESTS.—Diss. ·1 gm of Na_3AsO_3 in 3 c.c. of aq.

SH_2 (and HCl) : yellow ppt., As_2S_3, sol. in NH_4SH, NaOH and $(NH_4)_2CO_3$, no ppt. in neutral or alkaline solutions.

$AgNO_3$: lemon yellow ppt. of Ag_3AsO_3, soluble in NH_4OH and in acids.

$CuSO_4$: a ppt. of $CuHAsO_3$ (Scheele's green).

ARSENIC COMPOUNDS.

WET TESTS.—Diss. ·2 gm. Na_3AsO_4 in 6 c.c. aq.

SH_2 (and HCl) : warm and pass gas for some time : As_2S_3 and S.

NOTE.—Add H_2SO_3 to reduce pentad As compounds to triad As compounds.

$AgNO_3$: red brown ppt. of Ag_3AsO_4.

$CuSO_4$: green ppt, $CuHAsO_4$.

$MgSO_4$, NH_4Cl and NH_4OH ("magnesia mixture") : crystalline ppt. of $MgNH_4AsO_4$.

$FeCl_3$: yellowish ppt. of $FeAsO_4$.

$(NH_4)_2MoO_4$ warm with slight excess of conc. HNO_3 : yellow ppt. of Am, arseno-molybdate. (See P_2O_5 tests).

MARSH'S TEST.—All arsenious and arsenic compounds yield AsH_3 when added to a hydrogen generator, the H flame acquires a grey colour (from As_2O_3) and deposits a metallic film of arsenic on cold porcelain, and a mirror of As within the exit tube, if that be heated. The zinc and acid must be free from As; to prove this, ascertain whether a stain or mirror can be obtained from them before the As compound has been added. The mirror is sol. in NaClO.

FLEITMANN'S TEST.—Warm the As compound in a test tube with Zn and NaOH; the AsH_3 evolved blackens paper moistened with $AgNO_3$ sol.

REINSCH'S TEST.—Add a strip of bright Cu foil and a drop or two of HCl to the sol., let it stand some time : grey deposit of As; wash, dry and heat in bulb tube : crystals of As_2O_3.

Antimony. Sb, 119·1

DRY TESTS.—1. **Blowpipe.** Heat ·02 gm. Sb_2S_3 on char. with Na_2CO_3 : white brittle metallic beads (sol. in aq. regia) and white incrustation.

2. **Ignition tube.** Antimony and Sb_2S_3 when heated in a roasting tube (*i.e.*, one open at both ends) give a white sublimate of Sb_2O_3 and Sb_2O_4.

3. **Match test** : white, brittle metallic beads of Sb.

4. **Film test.** Velvet black; orange with SH_2 sol.

ANTIMONIOUS COMPOUNDS.

WET TESTS.—Diss. 0·1 gm. of Sb_2O_3 in 5 c.c. HCl : $SbCl_3$.

SH_2 (and HCl) : orange ppt. of antimonious sulphide Sb_2S_3, sol. in NaOH and in NH_4SH, and in boiling HCl, insoluble in $(NH_4)_2CO_3$. (See As).

NH_4OH : white ppt., Sb_2O_3, insol. in excess.

NaOH : white ppt., Sb_2O_3, sol. in excess to $NaSbO_2$ (Na metantimonite). Boil with bright copper foil and dil. HCl : deposit of metallic Sb; scrape off

and diss. in HCl and dilute : white ppt. of SbOCl ; next pass SH_2, the white ppt. turns to orange : Sb_2S_3.

Antimonic Compounds

Dissolve 0·1 gm. of K. antimonate, K_3SbO_4 in 5 c.c. aq.

HCl : ppt. sol. in excess of hot HCl.

SH_2 : orange ppt. of Sb_2S_5, Sb_2S_3 and S. Soluble in alkaline sulphides and hydroxides, with formation of antimonates and thio-antimonates.

$AgNO_3$: **white** ppt. of Ag_3SbO_4 ; (antimonious salts free from chlorine : a **black** ppt. of Ag_2O and Ag ; distinction between antimonic and antimonious salts).

Antimonic salts in presence of HCl also set free iodine from KI ; antimonious salts do not.

Tin. Sn, 118·1.

Dry tests—1. **Blowpipe.** Mix ·02 gm. SnO_2 with Na_2CO_3 and KCy and heat on char. in the **reducing** flame : white malleable beads, which do not mark paper, sol. in HNO_3 ; the HNO_3 sol. leaves a yellowish residue of metastannic acid $Sn_5O_5(OH)_{10}$ on evaporation to dryness ; metastannic acid is insol. in acids and in NaOH, but sol. after fusion with NaOH.

2. **Match test** : beads of metallic tin.

3. **Film test.** Black, with SH_2 aq. : yellow.

	Stannous Salts, *e.g.*, $SnCl_2$.	Stannic Salts, *e.g.*, $SnCl_4$.
	Wet tests.—Boil ·2 gm. tin with 5 c.c. HCl, dilute to 10 c.c.	Wet tests.—Diss. ·2 gm SnCl in 6 c.c. aq.
HCl	: no ppt.	: no ppt.
SH_2	: dark brown SnS, sol. in NaOH (yields Na stannite and thiostannite) ; also sol. in yellow NH_4SH, and in conc. hot HCl.	: yellow SnS_2, sol. in NaOH. (yields Na stannate and thiostannate) ; also sol. in NH_4HS
NH_4OH	: white ppt. of hydrated stannous oxide, $Sn(OH)_2$.	: white ppt. of H_2SnO_3 sl. sol. in excess and in tartaric acid.
NaOH	: white ppt. of $Sn(OH)_2$, sol. in excess to Na_2SnO_2, Na stannite.	: white ppt. of stannic acid, H_2SnO_3 sol. in excess, or of metastannic acid $Sn_5O_5(OH)_{10}$, difficulty sol. in NaOH and in acids.
$HgCl_2$	: white ppt. of HgCl ; boiled with excess of $SnCl_2$: Hg as a grey ppt.	: no change.
$AuCl_3$	: ppt. of purple of Cassius.	: no change.

Group IIIa.—Iron, Aluminium and Chromium.

Iron. Fe, 55·6.

Dry tests.—1. **Blowpipe.** Heat ·02 gm. of $FeSO_4$ on char. with Na_2CO_3, : black magnetic particles. Crush and wash in agate mortar; pick out the magnetic particles with a magnetised penknife blade. Place on filter paper, add HCl : yellow stain, add K_4FeCy_6 : Prussian blue.

2. **Match test** : Same as on char.

3. **Borax bead** : bottle green in inner flame; reddish in outer flame while hot, but yellow or colourless when cold.

Ferrous Salts.	Ferric Salts.
Wet tests.—Diss. 0·2 gm. $FeSO_4$ in 10 c.c. aq.	Wet tests.—Diss. ·2 gm. $FeCl_3$ in 10 c.c. aq.
NH_4OH : greenish ppt. $Fe(OH)_2$, rapidly oxidizes and blackens.	: reddish ppt. of $Fe(OH)_3$, in absence of organic matter.
NaOH : greenish ppt. $Fe(OH)_2$, rapidly oxidizes and blackens.	: reddish ppt. of $Fe(OH)_3$, in absence of organic matter.
SH_2 : no ppt.	: S is precipitated.
NH_4SH : black ppt. FeS.	: FeS and free S.
$(NH_4)_2CO_3$: greenish ppt., $FeCO_3$.	: Red ppt. of $Fe(OH)_3$.
K_4FeCy_6 : pale blue, $K_2Fe,FeCy_6$, which darkens and becomes $Fe_4(FeCy_6)_3$.	: Prussian blue, $Fe_4(FeCy_6)_3$.
K_3FeCy_6 : deep blue (Turnbull's) $Fe_3''(Fe'''Cy_6)_3$.	: no ppt.
KCNS : no change, the slightest trace of ferric salt gives a red colour	: blood red sol. *
Na_2HPO_4 : bluish ppt.	: reddish white $Fe'''(PO_4)$.
Tannic Acid : blue black ppt.	: blue black colour (ink).

Ferric salts are reduced and decolourized by Zn and HCl, by SO_2, $SnCl_2$, and other reducing substances.

Aluminium. Al, 26·9.

Dry tests.—**Blowpipe.** Strongly heat on char. or on Pt wire : white highly luminous residue. Moisten with $Co2NO_3$ and re-heat : blue mass. If the substance be in solution, moisten a scrap of filter paper with it, dry and ignite on Pt. wire in bunsen flame; moisten residue with $Co2NO_3$ and again ignite : blue residue.

* Sol. in ether, destroyed by $HgCl_2$, but not by HCl, the red colours of ferric formate and acetate are destroyed by dil. HCl, the red colour with meconates is not destroyed by $HgCl_2$.

WET TESTS.—Diss. 0·2 gm. of alum $KAl2SO_4, 12H_2O$ in 5 c.c. aq.

NH_4OH : white gelatinous $Al(OH)_3$, practically insol. in excess and in NH_4Cl.

NaOH : gelatinous $Al(OH)_3$, sol. in excess to Na_3AlO_3, and not reprecipitated on boiling ; reprecipitated by adding HCl and NH_4OH and boiling.

NH_4SH : white gelatinous $Al(OH)_3$ and SH_2 evolved.

$(NH_4)_2CO_3$: white gelatinous $Al(OH)_3$ and CO_2 evolved.

$(NH_4)_3PO_4$: white $AlPO_4$, sol. in NaOH, KOH and sparingly in NH_4OH, but insol. in NH_4Cl.

Chromium. Cr, 51·7.

DRY TESTS.—**Blowpipe.** (*a*) Borax bead : emerald green in both flames. (*b*) Fused on Pt foil with Na_2CO_3 and KNO_3 : yellow K and Na chromates. Diss. in acetic acid, add Pb acetate : yellow ppt. of Pb chromate.

WET TESTS.—Diss. ·2 gm chrome alum ($KCr2SO_4.12H_2O$) in 5 c.c. aq.

NH_4OH : green $Cr(OH)_3$, insol. in excess on boiling.

NaOH : green $Cr(OH)_3$, sol. in excess to a green or violet colour, but reprecipitated on boiling.

NH_4SH : green ppt. of $Cr(OH)_3$ and SH_2 evolved, insol. in excess.

$(NH_4)_2CO_3$: green ppt. of $Cr(OH)_3$.

Cl aq. or Br aq. in the cold oxidizes Cr salts to chromates.

Cr forms both basic and acid salts.

BASIC.	ACID.
CrO : chromous salts.	Chromates contain CrO_3 (yellow).
Cr_2O_3 : chromic salts, mostly green.	Bichromates contain $2CrO_3$ (red).

If the Cr be present as an acid radicle (CrO_3) it must be reduced to the basic condition by boiling with conc. HCl or with H_2SO_3 before applying the above wet tests.

Chromic Acid. H_2CrO_4

DRY TESTS.—The same as for basic Cr.

WET TESTS.—Diss. 0·1 gm. of $K_2Cr_2O_7$ in 5 c.c. aq. and divide into 5 parts.

HCl : deep red colour, becomes green ($CrCl_3$) on boiling with alcohol (or SO_2) or on passing SH_2 through it.

$BaCl_2$: yellow, $BaCrO_4$, sol. in acids.

$AgNO_3$: dark red Ag_2CrO_4.

$Pb2C_2H_3O_2$: yellow $PbCrO_4$.

H_2O_2 (in ether) and one drop of dil. HCl, shake : deep blue solution. (Due to the unstable Cr_2O_7.)

GROUP IV.—ZINC, MANGANESE, NICKEL AND COBALT.

Zinc. Zn, 64·9.

DRY TESTS—1. **Blowpipe.** Heated on char. in inner flame with $NaKCO_3$, Zn salts yield a yellow incrustation of ZnO,* white when cold; moisten with $Co2NO_3$ and again heat before blowpipe: green residue.

2. **Film test.**—Black, becomes white with SH_2 sol.

WET TESTS.—Diss. 0·1 gm. $ZnSO_4$ in 5 c.c. aq.

NH_4OH: white ppt. of $Zn(OH)_2$, in absence of NH_4 salts.

KOH or **NaOH**: white ppt. $Zn(OH)_2$, which is sol. in an excess of reagent; add NH_4SH: white ppt. of ZnS.

NH_4SH: white ppt. of ZnS insol. in excess, NH_4OH and NH_4Cl facilitate its precipitation from dil. sols. Sol. in HCl, HNO_3, and H_2SO_4, but insol. in acetic acid. (See Mn).

$(NH_4)_2CO_3$: white basic Zn carbonate, $ZnCO_3,3Zn(OH)_2$, sol. in excess.

KCy: white ppt. of $Zn(Cy)_2$, sol. in excess, from which it is precipitated by Na_2S as ZnS, but not by NH_4SH.

Manganese. Mn, 54·6.

DRY TESTS—**Blowpipe.** (*a*) Borax bead: an amethyst colour in the oxidising and a colourless bead in the reducing flame. (*b*) Fuse ·01 gm. MnO_2 with a little Na_2CO_3 and KNO_3 on Pt foil or wire: green-coloured mass of K and Na manganates; diss. this in a little very dilute H_2SO_4: red sol. of Na and K permanganates.

WET TESTS.—Diss. 0·1 gm. $MnSO_4$ in 5 c.c. aq.

NH_4OH: white ppt., $Mn(OH)_2$, sol. in NH_4Cl.

NaOH: white ppt. of $Mn(OH)_2$, insol. in excess; rapidly oxidizes and turns to brown Mn_2O_3,H_2O.

NH_4SH: pinkish ppt. of MnS; the fresh ppt. is sol. in acetic acid.

Na_2CO_3: white $MnCO_3$, sol. in NH_4Cl, oxidizes and becomes brown.

KCy: white $Mn(Cy)_2$, soluble in excess.

Nickel. Ni, 58·3.

DRY TESTS.—**Blowpipe.** (*a*) Borax bead: grey in inner, reddish in outer flame; a little KNO_3 renders the bead purple. (*b*) On char. with Na_2CO_3, or on match: black, slightly magnetic particles. Use magnetised penknife blade.

* Zinc is volatile, but ZnO is not.

WET TESTS.—Diss. 0·1 gm. of $NiSO_4$ in 7 c.c. of aq.

NH_4OH : light green ppt., $Ni(OH)_2$, sol. in excess to a blue solution.

NaOH : light green $Ni(OH)_2$ insol. in excess, but sol. in NH_4 salts, and in acids.

NH_4SH : black ppt., NiS, insol. in acetic and hydrochloric acids, slightly sol. in NH_4SH, and in NH_4OH. The sol. is brown.

NaClO sol., boil : black $Ni(OH)_3$.

$(NH_4)_2CO_3$: green ppt., basic $NiCO_3$, sol. in excess.

KCy : greenish ppt., $Ni(Cy)_2$, sol. in excess to a brown sol. of 2KCy, $NiCy_2$; reprecipitated by acids (see Co); to the sol. in KCy add Br aq. until of a permanent brown colour; warm : black ppt. of $Ni(OH)_3$.

K_4FeCy_6 : greenish ppt., Ni_2FeCy_6.

Cobalt. Co, 58·56.

DRY TESTS.—**Blowpipe.** (*a*) Borax bead : blue in both reducing and oxidizing areas. (*b*) On char. with Na_2CO_3, or with match test : black magnetic particles. Use magnetised penknife blade.

WET TESTS.—Diss. ·2 gm. of $Co2NO_3$ in 7 c.c. aq.

NH_4OH, in absence of NH_4Cl, : blue ppt. of basic salt, sol. in excess to a brown sol., which momentarily becomes purple on boiling.

NaOH : a blue ppt. of basic salt, $Co(OH)_2,Co2NO_3$, insol. in excess, becomes green on standing, and pink, ($Co(OH)_2$) or brown on warming, dissolves in $(NH_4)_2CO_3$ (after washing) to a deep purple sol.

NH_4SH : a black ppt. of CoS difficultly sol. in dil. HCl or H_2SO_4, but readily sol. in warm aqua regia.

$(NH_4)_2CO_3$: rose coloured ppt., sol. in excess.

KCy : brown ppt. of $CoCy_2$, sol. in excess to $2KCy,CoCy_2$; when **boiled** with a drop of HCl to set free HCy, K_3CoCy_6 (pot. cobalti-cyanide) is formed, from which $Co(OH)_3$ is not precipitated by HCl nor by NaClO. (Compare $NiCy_2$). **To separate Co and Ni** by this reaction, add KCy until the ppt. only just redissolves, then add two or three drops of acetic acid, boil for three minutes; cool, filter off any ppt. which forms, make alkaline with NaOH, add **Br aq.** until the sol. remains yellow to brown in colour, warm : black ppt. of $Ni(OH)_3$. Filter, evaporate filtrate and test for Co by borax bead.

K_4FeCy_6 : a dark green ppt. of Co_2FeCy_6.

KNO_2 and acetic acid to a neutral sol. : bright yellow crystalline ppt. of $K_3Co(NO_2)_3$ (pot. cobaltinitrite). This reaction also serves for the separation of Co from Ni; add two or three c.c. of alcohol and shake the mixture, let stand for fifteen or twenty minutes, filter off the $K_3Co(NO_2)_3$, and add NaOH to the filtrate : $Ni(OH)_3$.

Group V.—Barium, Strontium and Calcium.

Barium. Ba, 136·4.

Dry test.—Ba salts colour the bunsen flame pale green, especially when moistened with HCl.

Wet tests.—Diss. 0·1 gm $BaCl_2$ in 5 c.c aq.

$(NH_4)_2CO_3$: white ppt. of $BaCO_3$, sol. in dil. HCl, slightly soluble in NH_4Cl.

$CaSO_4$ or other sulphates or dil. H_2SO_4 : an immediate ppt. of $BaSO_4$ even in dil. sols. Insol. in dil. acids and alkalis.

$(NH_4)_2C_2O_4$: white granular ppt. of BaC_2O_4.

K_2CrO_4 : pale yellow ppt. of $BaCrO_4$ from even dil. sols. ; sol. in HCl and HNO_3 ; insol. in acetic acid ; $SrCrO_4$ and $CaCrO_4$ are sol.

H_2SiF_6 gives a white crystalline ppt. of $BaSiF_6$, hastened by the addition of alcohol ; Ca and Sr salts are not precipitated by H_2SiF_6.

Strontium. Sr, 86·94.

Dry test.—Sr salts colour the flame red.

Wet tests.—Diss. 0·1 gm. of $SrCl_2$ in 5 c.c. aq.

$(NH_4)_2CO_3$: white ppt. of $SrCO_3$.

H_2SO_4 (dil.) or a sol. sulphate throws down white $SrSO_4$. If $CaSO_4$ is used or the sol. be dilute the ppt. will take some time to form ; hastened by boiling with $(NH_4)_2SO_4$, in which $CaSO_4$ is soluble.

Na_2HPO_4 ; a white ppt. of Sr_32PO_4.

$(NH_4)_2C_2O_4$: white ppt. of SrC_2O_4.

K_2CrO_4 : pale yellow ppt. of $SrCrO_4$, sol. in acetic and other acids.

Calcium. Ca, 39·8.

Dry test.—Ca salts colour the flame orange red.

Wet tests.—Diss. ·1 gm. $CaCl_2$ in 5 c.c. aq.

$(NH_4)_2CO_3$, in the presence of NH_4Cl, gives a white ppt. of $CaCO_3$. Ignite ppt. on Pt wire : CaO ; place this residue on moist red litmus paper : blue.

H_2SO_4, or a sulphate (except $CaSO_4$) : white ppt. of $CaSO_4$ from strong sols., or from weak ones on adding alcohol.

Na_2HPO_4 and NH_4OH : bulky white ppt. of $Ca_3P_2O_8$, sol. in HCl and HNO_3.

$(NH_4)_2C_2O_4$: white ppt. of Ca oxalate (CaC_2O_4) insol. in acetic acid ; sol. in HCl.

K_2CrO_4, no ppt. unless the solution is very strong.

GROUP VI.—MAGNESIUM, POTASSIUM, SODIUM, AMMONIUM AND LITHIUM.

Magnesium. Mg, 24·18.

DRY TEST.—**Blowpipe.** Mg salts on char. or Pt wire : a white luminous residue, moisten this with $Co2NO_3$ and heat strongly : pink residue.

WET TESTS.—Diss ·1 gm. $MgSO_4$ in 4 c.c. aq.

NH_4OH : white gelatinous ppt. of $Mg(OH)_2$ *i.e.*, in the absence of NH_4Cl, otherwise soluble double salts are formed.

KOH, NaOH, $Ca(OH)_2$, and $Ba(OH)_2$ throw down $Mg(OH)_2$ in the absence of NH_4 salts. $Mg(OH)_2$ is only slightly soluble in aq.

$(NH_4)_2CO_3$: white crystalline ppt. of $Mg(NH_4)_22CO_3$ (after some time) if NH_4 salts are absent.

Na_2HPO_4 in the presence of NH_4OH and NH_4Cl : crystalline ppt. of $Mg(NH_4)PO_4$, especially when stirred or shaken. Dilute solutions should be allowed to stand some time.

Potassium. K, 38·86.

DRY TESTS.—1. K salts colour the bunsen flame lilac to violet; if the flame be yellow from the presence of sodium examine it through blue glass or an indigo prism, so as to cut out the yellow rays; if lithium be present, view the flame through four or five thicknesses of blue glass.

2. Confirm with spectroscope.

3. **Blowpipe.** On charcoal, K salts fuse and sink into the charcoal, and colour the flame greyish or pale lilac.

WET TESTS.—Diss. ·2 gm. KCl in 3 c.c. aq.

Chloroplatinic Acid, "Platinum chloride," **(H_2PtCl_6)** : a yellow crystalline ppt. of K_2PtCl_6, insol. in acids and in alcohol; sol. in KOH.

Tartaric Acid, $H_2C_4H_4O_6$, or **sodium hydrogen tartrate** $NaHC_4H_4O_6$: white crystalline ppt. of $KHC_4H_4O_6$ from neutral solutions; its formation is hastened by stirring and shaking, and by the addition of alcohol.

H_2SiF_6 : a gelatinous ppt. of K_2SiF_6, sol. in aq. (1 in about 800); insoluble in alcohol.

Sodium. Na, 22·88.

DRY TEST.—Na salts colour the bunsen flame yellow; seen through blue glass or an indigo prism it appears colourless.

WET TESTS.—There are no satisfactory tests for sodium in solution.

Ammonium. (NH_4)

DRY TESTS.—1. **Ignition tube.** Most ammonium salts when heated in a dry tube yield a white sublimate, either with or without the evolution of NH_3, which is recognised by its smell and the bluing of red litmus.

2. Ammonium salts warmed with $Ca(OH)_2$ or NaOH sol. : NH_3 gas.

WET TESTS.—Diss. ·2 gm. NH_4Cl in 3 c.c. of aq.

Chloroplatinic acid, "Platinum chloride," $\mathbf{H_2PtCl_6}$: yellow ppt. of $(NH_4)_2PtCl_6$ similar to that from K salts; ignite the $(NH_4)_2PtCl_6$ on porcelain : residue of grey spongy platinum.

Tartaric acid, $H_2C_4H_4O_6$: white crystalline ppt. of $(NH_4)HC_4H_4O_6$; ignite : carbon free from alkaline reaction.

Nessler's test for minute traces of NH_3 : a yellow or brown colouration (due to NHg_2I,H_2O). Test for NH_3 in the distilled aq. used.

Lithium. Li, 6·98.

DRY TESTS.—Li salts colour the bunsen flame crimson; Na changes it to orange, but the Li is recognisable if the flame be viewed through the thinner parts of the indigo prism. A silicate must be fused with $CaSO_4$, and Li_3PO_4 moistened with HCl to obtain the flame colouration. Li is easily recognised in the spectroscope by the single red and orange bands.

WET TESTS.—Diss. 0.1 gm. of LiCl in 3 c.c. of aq.

$\mathbf{Na_2HPO_4}$ **and NaOH,** boil : a white crystalline ppt. of $2Li_3PO_4,H_2O$. If traces only of Li are present, add Na_2HPO_4 and NaOH, and evaporate to dryness and wash the residue with dil. NH_3.

$\mathbf{Na_2CO_3}$, (K_2CO_3 or $(NH_4)_2CO_3$) with an equal vol. of alcohol : ppt. of Li_2CO_3. **Lithium in waters.** Concentrate, add $Ba(OH)_2$ and cool; then add $(NH_4)_2CO_3$ and filter; to the filtrate add Na_3HPO_4, take up with a small quantity of aq., residue : Li phosphate. Confirm by the flame test. Li differs from K and NH_4 by not being precipitated by H_2PtCl_6 or by $H_2C_4H_4O_6$. LiCl can be separated from KCl and NaCl by a mixture of absolute alcohol and ether, in which it is insoluble.

RARER METALS OF GROUP I.—TUNGSTEN, THALLIUM AND NIOBIUM.

Tungsten or Wolfram. W, 182·6.

DRY TESTS.—**Blowpipe.** (*a*) Heat ·02 gm. Na_2WO_4 on char. with Na_2CO_3 and KCN : black impure tungsten. (*b*) **Microcosmic salt,** in outer flame : colourless or yellow bead; in inner flame : blue bead; re-fused with a little powdered $FeSO_4$: blood red when cold.

WET TESTS.—Diss. 0·1 gm. Na_2WO_4 in 5 c.c. aq.

HCl, HNO_3 or **H_2SO_4** : white ppt. of H_2WO_4; yellow on boiling, sol. in NH_4OH; add fragment of zinc : blue colour.

SH_2 : no ppt., but H_2WO_4 is reduced to the blue W_2O_5.

HCl and **Zn** : the deep blue W_2O_5, turning to brown WO_2.

$SnCl_2$ in neutral sol. : yellow ppt. of WO_2 (?) add HCl and warm : blue.

NH_4SH : no ppt. until HCl is added, the sol. turns blue and a brown ppt. of WS_3 forms; readily sol. in NH_4SH.

Thallium. Tl, 202·6.

Thallium is partly thrown down as chloride in Group I with Pb, etc., also in Group II with As, and partly as sulphide in Group IV. Examine As_2S_3 for Tl, as Tl may come down with it.

DRY TESTS.—**Flame test** : strong green colour, and one bright green band in the spectrum.

THALLIOUS COMPOUNDS.

WET TESTS.—Diss. ·1 gm, Tl_2SO_4 in 7 c.c. aq.

HCl : white ppt. of TlCl, sol. in aq. regia; is not blackened by light Slightly sol., hence not formed in dil. solutions.

SH_2 : black Tl_2S, only partly precipitated, except in acetic acid sol.

KI : yellow ppt. TlI, nearly insol. in aq., more sol. in KI.

H_2PtCl_6 : orange ppt., Tl_2PtCl_6 slightly sol. in aq.

NH_4SH : black ppt., clots on boiling, insol. in NH_4OH, in alkaline sulphides and in KCN; oxidised by the air to Tl_2SO_4, which is readily sol. in mineral acids.

K_2CrO_4 : yellow Tl_2CrO_4 insol. in cold HNO_3.

Zn : metallic Tl.

THALLIC COMPOUNDS.

WET TESTS.—Diss. ·01 gm. $TlCl_3$ in 5 c.c. aq.

HCl : no ppt.

SH_2 : reduces thallic to thallious salts, with separation of S.

KI : ppt. of yellow TlI, and free I.

K_2CrO_4 : no ppt.

$H_2C_2O_4$: white ppt. of Tl oxalate.

To detect Tl in pyrites, etc., and in the residue left by Zn when dissolved in HCl, diss. in aq. regia, add H_2SO_4 and boil off the HNO_3, add Na_2SO_3 to reduce to ferrous and thallious salts, then add KI, when yellow TlI is precipitated.

Niobium or Columbium. Nb, 93·3.

DRY TEST.—**Blowpipe.** Microcosmic salt : colourless bead in the OF while hot, in the RF : violet, blue, or brown ; add a little $FeSO_4$: red colour.

WET TESTS.—Diss. ·01 gm. $KNbO_3$ in 5 c.c. aq.

H_2SO_4 and other mineral acids : ppt. of $Nb(OH)_3$.

NH_4OH or NH_4SH : ppt. of $Nb(OH)_3$, sol. in HF.

K_4FeCy_6 and two drops of HCl : red ppt.

K_3FeCy_6 : yellow ppt.

Zn and **HCl** : blue ppt. which changes to brown.

RARER METALS OF GROUP IIA.—OSMIUM AND PALLADIUM.

Osmium. Os, 189·6.

DRY REACTION.—Volatilizes at a very high temperature as OsO_4 without fusion.

WET TESTS.—Diss. ·01 gm. OsO_4 in 5 c.c. aq.

SH_2 (in acid solutions) : brown black ppt. of OsS.

Alkalis and their carbonates : reddish brown ppt. of $Os(OH)_4$.

Tannic acid (or **alcohol**) and **HCl** reduce it to the blue osmious chloride, $OsCl_2$.

Indigo solution is bleached.

Na_2SO_3 : deep violet colour, and a ppt. of blue osmious sulphite gradually forms.

Palladium. Pd, 105·7.

DRY TEST.—Heat a small particle of $PdCl_2$ on porcelain : a residue of Pd. All Pd salts yields Pd on ignition.

PALLADIOUS SALTS.

WET TESTS.—Diss. ·05 $PdCl_2$ in 10 c.c. aq. and two drops HCl.

SH_2 or **NH_4SH** : black ppt. of PdS in neut. alk. and acid solutions, insol. in NH_4SH, but sol. in hot HCl or aq. regia.

NH_4OH : pink ppt. of $PdCl_2.2NH_3$, sol. in excess.

$HgCy_2$: yellowish gelatinous $PdCy_2$, slightly sol. in HCl, readily in NH_4OH ; heated : spongy Pd. (Characteristic.)

KI : black ppt. of PdI_2, sol. in excess of KI. (Characteristic.)

KCl : brown red $2KCl,PdCl_2$, on standing.

NH_4Cl : no ppt. (Difference from Pt).

Iodine (tincture) forms a black stain on Pd, but not on Pt.

$SnCl_2$: brown-black ppt., sol. in HCl to a green sol.

KOH : light brown basic salt, sol. in excess.

$Na_2S_2O_3$ (a few drops in NH_4OH) : pale yellow solution ; on boiling becomes black.

PALLADIC SALTS.

WET TESTS.—Diss. 1 mgm. of $PdCl_4$ in 2 c.c. aq.

KOH : brown ppt. of $Pd(OH)_4$. Boil : black PdO_2.

KCl : bright red crystalline ppt. of $2KCl,PdCl_4$ or K_2PdCl_6.

THE RARER METALS OF GROUP IIB.—GOLD, PLATINUM, IRIDIUM, MOLYBDENUM, SELENIUM AND TELLURIUM.

Gold. Au, 195·7.

DRY TEST.—**Blowpipe.** Heated on char. or on match, all gold compounds are decomposed and the metal is left ; if the charcoal or match end be ground in an agate mortar and the charcoal be very carefully washed away, so as not to float off gold with it, very minute traces of gold can be detected in this way. The spangles of gold are insol. in H_2SO_4, in HCl free from Cl, and in HNO_3 free from N. oxides ; sol. in aq. regia.

WET TESTS.—Diss. ·01 gm. $NaAuCl_4,2H_2O$ (photographers' "gold chloride") in 10 c.c. aq.

SH_2 in cold sols. : black Au_2S_3 (auric sulphide).

SH_2 in hot sols. : brown Au_2S (aurous sulphide) mixed with free gold, if long boiled the whole is reduced to metallic gold. Both Au_2S and Au_2S_3 are sol. in aq. regia, in yellow NH_4SH, and in yellow Na_2S.

$FeSO_4$: ppt. of metallic gold.

SO_2 : ppt. of metallic gold.

$H_2C_2O_4$ on warming : ppt. of metallic gold.

NH_4OH : pale orange ppt. of fulminating gold (Au, N, and NH_3) sol. in excess. This ppt. explodes with great violence, especially when dried and heated.

$SnCl_2$ and three drops of **$FeCl_3$** : purple of Cassius.

P dissolved in ether, : red or purple colour, even in exceedingly dil. $AuCl_3$, say one part of Au in 1,000,000 of aq.

Zn and **most metals** precipitate gold from its solutions.

Iodine tincture readily dissolves out traces of gold from quartz, etc. Agitate five or ten grammes of the finely-powdered mineral with a tincture of iodine, let stand, dip a strip of white filter paper into the clear liquid, dry and burn ; if gold be present the ash will be purple or brown, if much gold be present, on rubbing the ash in a mortar (agate) it will show the colour of

burnished gold. Merely grinding ores in an agate mortar and washing carefully is usually quite sufficient to detect even traces of gold. But where it is practicable the ore may be first treated with HCl free from Cl, or HNO_3 free from N. oxides, to remove other metals; remove silica by HF.

Platinum. Pt, 193·3.

DRY TEST.—Heat 0·1 gm. or less of $PtCl_4$ on char. or match, crush in agate mortar and wash away the char. powder : grey metallic Pt. Insol. in H_2SO_4, in HCl and in HNO_3, but sol. in aq. regia.

WET TESTS.—Dissolve ·05 gm. H_2PtCl_6 in 7 c.c. aq.

SH_2 : dark brown ppt. of PtS_2, favoured by warming; insol. in HCl and HNO_3, but sol. in aq. regia and in yellow NH_4SH.

NH_4SH : PtS_2, as above.

NH_4Cl and 2 c.c. alcohol : yellow crystalline ppt. of $(NH_4)_2PtCl_6$.

KCl and 2 c.c. alcohol : yellow crystalline ppt. of K_2PtCl_6.

Zn : ppt. of metallic Pt.

$SnCl_2$: brown-red colour from formation of $PtCl_2$.

To separate Au and Pt from solution, reduce the Au by $H_2C_2O_4$, filter off, and then evaporate with NH_4Cl to obtain the Pt as $(NH_4)_2PtCl_6$.

Iridium. Ir, 191·5.

DRY TESTS.—1. Fused with $KHSO_4$ it is oxidized, but not dissolved. (Distinction from Rh.) 2. Heat a minute particle of any Ir salt on char. or porcelain : finely-divided Ir.

WET TESTS.—Diss. ·02 gm. $IrCl_3$ in 5 c.c. aq.

SH_2 : the colour is discharged, S set free, and a brown ppt. of iridic sulphide Ir_2S_3 forms.

NH_4SH : same as SH_2; sol. in excess.

KOH in excess : green colour, and a dark brown ppt. of K_2IrCl_6; warm the solution : red colour changing to blue (distinction from Pt); evaporate to dryness with aq. : blue residue of IrO_2.

KCl : dark brown ppt. of K_2IrCl_6.

NH_4Cl, from strong sols. : dark red crystalline ppt. of $(NH_4)_2IrCl_6$

Molybdenum. Mo, 95·3

DRY TESTS.—1. In bunsen flame : yellowish green colour.

2. **Blowpipe.** On char., or match, in inner flame : grey powder of Mo; in outer flame : yellow crystalline incrustation, white on cooling.

3. **Borax bead.** In outer flame, yellow; in inner, dark brown bead.

4. **Microcosmic salt.** Green bead in inner and outer flames.

WET TESTS.—Diss. 0·1 gm. $(NH_4)_2MoO_4$ in 10 c.c. aq.

HCl (or **HNO_3** or **H_2SO_4**) on boiling throws down white MoO_3, sol. in excess of acid; evaporate to dryness with H_2SO_4 : blue colour.

SH_2 (in acid sol.) : a blue colour and then a brown ppt. of MoS_3; warm and pass SH_2 for some time for complete precipitation. Sol. in alkalis and alk. sulphides.

NH_4SH : same as SH_2; sol. in excess.

$SnCl_2$, or Zn and HCl : brown, green or blue colour according to the degree of concentration.

KCNS, or zinc and HCl : crimson colour, which can be taken up by ether.

Na_2HPO_4 (or Na_3AsO_4) and HNO_3 on warming : yellow ppt., sol. in excess of alkalis.

In minerals, *e.g.*, Molybdenite (MoS_2), or Wulfenite ($PbMoO_4$), first heat with dil. HCl to dissolve out Fe and Zn, extract residue with strong HCl and evaporate to dryness. Digest with NH_4OH, filter and concentrate, when crystals of $(NH_4)_2MoO_4$ separate, to which the usual tests can be applied.

Selenium. Se, 78·5.

DRY TESTS—1. **Blowpipe.** (*a*) On char. in inner flame : odour of decaying horse-radish. Se burns with a bluish flame to SeO_2. (*b*) On char. with Na_2CO_3, in inner flame or on match : fused mass of Na selenide, Na_2Se; this placed on a silver coin and moistened yields a black stain, and with HCl the characteristic odour of SeH_2.

2. Heated in a roasting tube, selenides evolve a peculiar odour of decaying horse-radish and yield a red sublimate of Se.

SELENITES.

WET TESTS.—Diss. ·1 gm. of Na selenite (Na_2SeO_3) in 7 c.c. aq.

SH_2 in **cold** acid sol. : yellow ppt.; in **hot** sol. : an orange ppt. (SeS_2 ?) which soon decomposes into free S and Se, sol. in NH_4SH.

$BaCl_2$, in neutral sols. : white ppt. of $BaSeO_3$, sol. in HCl and in HNO_3.

$SnCl_2$ or H_2SO_3 (and 2 drops of HCl) : red ppt. of Se, which becomes grey on heating.

Cu and HCl, warm : ppt. of black Se, which after standing becomes red.

Mg or Zn in slightly acid sols. : red flakes of Se. Diss. out any excess of Mg or Zn with HCl; the Se is left in the form of the metallic fragments of Mg or Zn.

KI : scarlet ppt. of SeI_4. This on heating quickly sublimes, the sublimate is hardly distinguishable from that of Se itself.

Selenates also give the above reactions after reduction to selenites by boiling with HCl.

SELENATES.

WET TESTS.—Diss. ·1 gm. of K_2SeO_4 in 3 c.c. aq.

HCl : no change; boil, Cl is evolved and the selenate is reduced to selenite.

SH_2 : no ppt. at first, *i.e.*, until the selenate has been reduced to selenite by the SH_2.

$BaCl_2$: a white ppt. of $BaSeO_4$, insol. in cold but sol. in hot HCl, with evolution of Cl and reduction to Ba selenite.

Tellurium. Te, 126.

DRY TESTS.—1. **Blowpipe.** On char. : thin white incrustation.

2. **Tellurides, Tellurites and Tellurates** when fused with Na_2CO_3 on char. or on match in the inner flame : Na telluride; this placed on a silver coin and moistened produces a black stain, and with HCl it yields black Te, and TeH_2 which smells something like SH_2.

3. For minerals (Tellurides) use KCy as well as Na_2CO_3.

4. Tellurides heated in a roasting tube : white fusible sublimate of TeO_2.

To extract from minerals, fuse ·2 gm. with ten times the weight of KCy in a bent, hard-glass tube through which H is passed, K_2Te is formed. Extract this with aq. : red solution; on passing a current of air through this, scales of Te are precipitated; heat on char., a slight odour is emitted and white TeO_2 is deposited.

TELLURITES.

WET TESTS.—Diss. ·2 gm. of K_2TeO_3 in 6 c.c. aq. or ·1 gm. Te in 5 c.c. of strong HNO_3, and nearly neutralize with NaOH.

H_2O : ppt. of white H_2TeO_3 (from acid sols.)

HCl : ppt. of white H_2TeO_3 (from the HNO_3 sol.)

SH_2 : ppt. of brown TeS_2 in acid sols., easily sol. in NH_4SH.

H_2SO_3, $SnCl_2$, or Zn and HCl : ppt. black Te; insol. in KCy.

TELLURATES.

WET TEST.—Diss. 0·1 gm. K_2TeO_4 in 2 c.c. aq.

HCl : no change: boil, Cl is evolved and the tellurate is reduced to tellurite; on dilution, H_2TeO_3 comes down.

THE RARER METALS OF GROUP III.

are thrown down by NH_4OH as hydroxides or acids:—

Beryllium hydroxide		$Be(OH)_2$	Zirconium hydroxide		$Zr(OH)_4$
			Thorium	,,	$Th(OH)_4$
Scandium hydroxide		$Sc(OH)_3$			
Yttrium	,,	$Y(OH)_3$	Titanium hydroxide		H_2TiO_3
Ytterbium	,,	$Yb(OH)_3$	Tantalum	,,	H_3TaO_4
Cerium	,,	$Ce(OH)_3$	Niobium	,,	H_3NbO_4
Lanthanum	,,	$La(OH)_3$			

The reactions for the salts of Scandium, Yttrium, and of some of the other rare metals are omitted on account of the difficulty of obtaining them in a pure condition.

Beryllium (Glucinum.) Be, 9.

DRY TEST. — **Blowpipe.** On char. with Co_22NO_3 : a grey mass ; not distinctive.

WET TESTS.—Diss. 0·1 gm. $BeSO_4$ in 5 c.c. aq.

NH_4OH, ($NaOH$, KOH or NH_4SH) throws down flocculent $Be(OH)_2$, sol. in KOH, but reprecipitated by dilution and long boiling; not sol. in NH_4OH, but the fresh ppt. is slowly dissolved by boiling with NH_4Cl.

Alk. carbonates : white ppt. of basic carbonate, sol. in excess, reprecipitated on dilution and long boiling, thus distinguished from Al.

$BaCO_3$: white Be carbonate.

To separate BeO from Al_2O_3. Diss. in HCl, pour slowly, with constant stirring, into a hot conc. sol. of $(NH_4)_2CO_3$: ppt. of $Al(OH)_3$; filter, neutralize with HCl, boil, add NH_4OH : ppt. of $Be(OH)_2$.

Cerium. Ce. 139·0.

DRY TESTS.—1. **Blowpipe.** On charcoal : reddish brown CeO_2.

2. **Borax bead,** outer flame : red when hot, colourless when cold; inner flame : colourless; but CeO_2 : yellow opaque bead.

CEROUS SALTS.

WET TESTS.—Diss. ·05 gm. $CeCl_3$ in 8 c.c. of aq.

NH_4OH : white ppt. of the basic salt; tartaric acid prevents this, (distinction from Y) ; insol. in excess, becomes yellow on exposure.

NaOH : white gelatinous ppt. $Ce(OH)_3$, somewhat soluble, gradually oxidizes and becomes yellow ; Cl water, NaClO, etc., bring about the same change more quickly.

$(NH_4)_2S$: $Ce(OH)_3$, cerous hydroxide, insol. in excess.

$H_2C_2O_4$: curdy white ppt. of Ce. oxalate, insol. in excess (distinction from Zr), difficultly sol. in HCl (Al and Be oxalates are soluble). Converted into CeO_2 on roasting.

NaClO, or Am. persulphate on boiling : yellow or red ppt.

Na_2CO_3, K_2CO_3 or $(NH_4)_2CO_3$: ppt. of Ce_23CO_3.

$BaCO_3$: complete precipitation on standing.

$KHSO_4$ saturated sol. : crystalline ppt. of $Ce_2(SO_4)_3,3K_2SO_4$ (distinction from Be and Al); insol. in a saturated sol. of K_2SO_4 (distinction from Y and Er).

CERIC SALTS.

The salts of CeO_2 are yellow and insoluble, or sparingly sol. in aq.

Lanthanum. La, 137·9.

DRY TEST.—**Blowpipe**. La_2O_3 undergoes no change.

WET TESTS.—Diss. ·01 gm. $LaCl_3$ in 4 c.c. aq.

NH_4SH **and** NH_4OH : ppt. of basic salts; milky on washing.

NaOH : La hydroxide, $La(OH)_3$, insol. in excess; unchanged by oxidising reagents (distinction from Ce).

$(NH_4)_2CO_3$: white ppt., insol. in excess (distinction from Ce).

Didymium. (Neodymium 142·5 and Praseodymium 139·4.)

DRY TEST.—**Blowpipe**. Heated on char. Di salts leave a grey residue.

WET TESTS.—Diss. ·01 gm. $DiCl_3$ in 5 c.c. aq.

NH_4OH **and** NH_4SH : basic salt, insol. in NH_4OH, but somewhat sol. in NH_4Cl.

NaOH : pale rose-coloured gelatinous $Di(OH)_3$, insol. in excess.

Na_2CO_3 : $Di(CO_3)_3$, insol. in excess (distinction from Ce), but slightly sol. in NH_4Cl.

$BaCO_3$: $Di(CO_3)_3$, slowly and incompletely.

$(NH_4)_2C_2O_4$: ppt., slowly sol. in cold HCl; readily on warming.

Di sols. yield characteristic absorption bands in the spectroscope.

Zirconium. Zr, 89·9.

DRY TESTS.—1. **Blowpipe**. ZrO_2 becomes strongly luminous; re-heat with $Co2NO_3$: a dull violet colour.

2. **Borax bead**, colourless; somewhat opaque when cold.

WET TESTS.—Diss. .05 gm. $Zr(SO_4)_2$ in 10 c.c. aq.

NH_4OH : white flocculent ppt. of $Zr(OH)_4$, insol. in excess and in NaOH. (Distinction from Al and Be).

NH_4SH : same as NH_4OH.

NaOH : same as NH_4OH, but soluble in boiling NH_4Cl. (Distinction from Be)

$(NH_4)_2CO_3$: white flocculent ppt. of basic carbonate, sol. in excess, reprecipitated on boiling. (Distinction from Al.)

$BaCO_3$: no ppt. cold, partly precipitated when boiled.

$H_2C_2O_4$: voluminous white ppt. of Zr oxalate (distinction from Al and Be); sol. in excess of $(NH_4)_2C_2O_4$ (distinction from Th and Ce.)

$Na_2S_2O_3$, boil : ppt. of ZrS_2O_3. (Distinction from Y, Er and Di.)

K_2SO_4 with $Zr(SO_4)_2$: ppt. of the double sulphate of Zr and K, insol. in excess of K_2SO_4, sol. in HCl. (Distinction from Al and Be.)

K_2SO_4 is added to **hot** $Zr(SO_4)_2$: the double sulphate is almost insol. in H_2O and HCl. (Distinction from Th and Ce.)

Thorium. Th, 230·8.

DRY TESTS.—1. **Blowpipe.** ThO_2 is infusible ; no characteristic colour with $Co2NO_3$.

2. **Borax bead** : colourless.

WET TESTS.—Diss. ·2 gm. $Th2SO_4$ in 8 c.c. aq.

NH_4OH or NaOH : white gelatinous $Th(OH)_4$, insol. in excess.

NH_4SH : same as NH_4OH or NaOH.

$(NH_4)_2CO_3$, Na_2CO_3 or K_2CO_3 : ppt. of white basic carbonate, readily sol. in excess, but reprecipitated from $(NH_4)_2CO_3$ at 50°.

$BaCO_3$: $Th2CO_3$ without warming.

$H_2C_2O_4$: white $Th2C_2O_4$ (distinction from Al and Be), not sol. in excess nor in dil. mineral acids ; sol. in $NH_4C_2H_3O_2$ acidulated with $HC_2H_3O_2$ (distinction from Y and Ce) ; sol. in hot Am. oxalate (distinction from Ce).

HF : gelatinous ThF_4, which gradually becomes granular ; insol. in H_2O and HF (distinction from Al, Be, Zr, Zn and TiO_2).

$Na_2S_2O_3$: from neutral or acid sols. partially precipitates ZrS_2O_3, mixed with free S.

Titanum. Ti, 47·7.

DRY TESTS.—1. **Blowpipe.** On char. : no change.

2. **Microcosmic salt bead** in outer flame : **yellow** while hot, **colourless** when cold ; in inner flame : **yellow** while hot, **violet** when cold. Add a particle of Sn or Zn to the bead and re-fuse in the reducing flame : brighter violet, or add a particle of $FeSO_4$: a blood-red bead in the inner flame.

WET TESTS.—(*a*) **Boil 0·1 gm.** TiO_2 in 3 c.c. conc. H_2SO_4 or HCl, dilute with 5 c.c. aq. and filter. (*b*) **To dissolve the** TiO_2 **completely,** fuse ·1 gm. with $KHSO_4$ on a porcelain lid; dissolve the yellow mass in cold water, then add a few drops of HCl to make a clear solution.

The alkalis, their sulphides and carbonates, and $BaCO_3$ give white flocculent ppts. of orthotitanic acid, H_2TiO_3, insol. in excess; if precipitated and washed in the cold it is sol. in HCl and H_2SO_4; **hot aq.** converts it into the insoluble metatitanic acid.

Zn or Sn in acid sols.: blue; if dilute: a rose colour. The TiO_2 is reduced to blue or purple Ti_2O_3, this gradually oxidizes to TiO_2 and loses colour.

$Na_2S_2O_3$ on boiling completely precipitates white TiO_2.

K_4FeCy_6: dark brown ppt. (the presence of Fe interferes.)

Tannic acid: brown ppt., changing to orange.

Tantalum. Ta, 181.6.

DRY TESTS.—1. **Blowpipe.** Ta_2O_5 becomes yellow when strongly ignited, and insol. in HCl and H_2SO_4.

2. **Microcosmic salt** bead: colourless in both flames.

WET TESTS.—Diss. ·02 gm. $KTaO_3$ in 5 c.c. aq.

HCl: ppt. of Ta_2O_5, sol. in excess of HCl.

NH_4OH **or** NH_4SH: a ppt. ($HTaO_3$ or $NH_4TaO_3,HTaO_3$?).

K_4FeCy_6: white ppt.; add NH_4OH: brown.

K_3FeCy_6: yellow ppt.

Zn and HCl: no change or a faint blue colour. (Distinction from Nb_2O_5)

THE RARER METALS OF GROUP IV.

Thrown down by NH_4SH as:

Uranyl sulphide $(UO_2)S$
Indium sulphide InS
Thallious sulphide Tl_2S (also in Group I).

Vanadium compounds are converted by NH_4SH into soluble ammonium thio-vanadate from which HCl precipitates V_2S_3.

Uranium. U, 236·7.

DRY TESTS.—**Blowpipe.** Borax and microcosmic salt beads in outer flame: yellow; in inner flame: green bead. Not reduced on char. with Na_2CO_3.

In minerals. Roast a small quantity of the mineral and diss. in HNO_3, evaporate to dryness; take up with water, filter (or add an excess of Na_2CO_3 and boil, filter off the carbonates of Fe, Ca, etc.) and add KOH, when the yellow $U(OH)_4$ is thrown down.

Uranous Salts.

Uranous salts are green or greenish.

Wet tests. Diss. 0·1 gm. $U(SO_4)_2$ in 5 c.c. aq., or reduce ·1 gm. uranic nitrate by Zn and HCl.

NH_4SH : black uranous sulphide, US.

Alkalis : brown gelatinous uranous hydroxide $U(OH)_4$.

Alk. carbonates : green uranous hydroxide, sol. in excess.

$AuCl_3$, $AgNO_3$: ppt. of Au or Ag.

Ferric salts are reduced to ferrous salts.

Uranic Salts.

Uranic salts are yellow.

Wet tests.—Diss. 0·1 gm of Uranylic nitrate $UO_2(NO_3)_2$ in 10 c.c. aq.

NH_4OH, KOH and NaOH : yellow ppt. of $(NH_4)_2U_2O_7$, insol. in excess.

NH_4SH, in neutral sols. : a dull yellow or brown ppt. of uranylic sulphide, UO_2S, precipitation is hastened by NH_4Cl, sol. in $(NH_4)_2CO_3$; sol. in acetic and other acids. Boiled with NH_4SH in excess it changes to black UO and S.

$(NH_4)_3PO_4$: white ppt.

H_2S : no ppt. in acid sols.

$(NH_4)_2CO_3$, Na_2CO_3 and K_2CO_3 : yellow ppt. of the double carbonates (*e.g.*, pot. uranic carbonate), readily sol. in excess, reprecipitated by boiling with NaOH, thus differing from Fe.

K_4FeCy_6 in acid sols. : reddish brown ppt. (Characteristic).

$BaCO_3$ completely precipitates U in the cold; hence it separates U from Ni, Co, Mn, Fe″ and Zn.

Zn and HCl : a green colour, no ppt.

Indium. In, 113·1.

Dry tests.—1. **On charcoal** : white ductile beads.

2. **Flame test** : bluish colour; its spectrum shows a bright blue and pale violet line.

In minerals. Extract with HCl, pour off the clear liquid after 24 hours and add a few drops of dil. H_2SO_4 to the residue, wash thoroughly with hot

aq. ; add HNO_3 and a few drops of H_2SO_4, evaporate nearly to dryness, add aq. and filter. Add NH_4OH in large excess to filtrate, filter, wash ppt. and diss. in a very little HCl, add excess of $NaHSO_4$ and boil, when $2In_2O_3 3SO_2,8H_2O$ separates out.

WET TESTS.—Diss. ·01 gm. of $In_2 3SO_4$ in 5 c.c. aq.

Alkalis : ppt. of $In(OH)_3$, white and voluminous, insol. in excess.

Alkaline carbonates : gelatinous ppt. of $In_2 3CO_3$.

SH_2 : no ppt. except in dil. and slightly acid sols., but it is wholly precipitated in the presence of acetic acid as yellow sulphide, In_2S_3, sol. in boiling NH_4SH, from which the white sulphide separates on cooling.

NH_4SH, tartaric acid and an excess of **NH_4OH** : a white ppt. of In_2S_3, turned yellow by acetic acid; sol. in hot NH_4SH.

Zinc and HCl : metallic In.

Gallium. Ga, 69·5.

Occurs in certain zinc blendes, etc. Best sought for by aid of the spectroscope.

Vanadium. V, 50·8.

DRY TESTS.—**Blowpipe.** Borax bead in outer flame, colourless or yellow; in inner flame green, hot and cold. If much V be present the bead is brown hot and green when cold.

WET TESTS.—Diss. 0·1 gm. of Na metavanadate ($NaVO_3$) in 7 c.c. aq.

NH_4SH in excess : brown colour; acidulate with H_2SO_4 : brown ppt. of V_2S_5, sol. in NH_4SH.

H_2S, H_2SO_3 or $H_2C_2O_4$ in acid sol. : blue colour due to reduction of the vanadates. With H_2S, S is also separated.

Zn and dil. H_2SO_4, warm : blue, changing to green and lavender.

NH_4Cl conc. sol., or NH_4OH and NH_4Cl : white ppt. of $(NH_4)_3VO_4$. (Characteristic).

H_2O_2 in ether, shake with two drops of HCl : red colour.

Gallic acid : blue black colour, disappears with excess of reagent.

K_3FeCy_6 : light green ppt.

In minerals. Boil with conc. HNO_3, remove Pb by H_2SO_4 and filter, wash ppt. with alcohol, the filtrate contains V_2O_5 : confirm by Zn and HCl.

THE RARER METALS OF GROUP VI.—RUBIDIUM AND CÆSIUM.

Rubidium. Rb, 84·8. Cæsium. Cs, 132.

DRY TESTS.—(*a*) Both Rb and Cs salts impart a greyish colour to the flame. (*b*) The spectra afford the best tests. Rb gives two characteristic lines in the red and two in the blue; Cs gives two light blue lines to the right of the Sr δ line.

WET TESTS.—Use sols. of $RbCl_2$ and $CsCl_2$.

$RbCl_2$ and $CsCl_2$: ppt. with H_2PtCl_6 and $H_2C_4H_4O_6$ similar to the Pt ppts.

The Rb_2PtCl_6 and Cs_2PtCl_6 are less sol. in aq. than K_2PtCl_6, hence the latter can be washed out by boiling with successive small quantities of aq.

REACTIONS OF THE ACIDS.

INORGANIC ACIDS.

Hydrofluoric Acid. HF.

DRY TESTS.—Most fluorides fuse, some give off HF gas, which attacks glass, all do when fused with $KHSO_4$. Mix the powdered fluoride with $KHSO_4$ and heat strongly in a piece of hard glass tubing, wash and dry the tube to render the etching visible. [NOTE. Do not inhale the gas.]

WET TESTS.—Diss. ·05 gm. of NaF or of NH_4F in 3 c.c. aq.

$CaCl_2$: a transparent gelatinous ppt. of CaF_2, insol. in HF.

H_2SO_4 conc., warm : HF is evolved, rinse out the tube, dry it, and note the corrosion of the tube.

$BaCl_2$: white ppt. of BaF_2, sol. in HNO_3 and in HCl.

H_2SO_4 and sand warmed with a dry fluoride : SiF_4, which deposits gelatinous silicic acid on a moist rod lowered into the test tube.

Hydrochloric Acid. HCl.

DRY TESTS.—**Blowpipe.** Chlorides heated in a microcosmic salt bead with a little CuO impart a vivid blue colour to the flame. Most chlorides fuse but some are decomposed on heating, *e.g.*, $AuCl_3$ and $PtCl_4$.

H_2SO_4 (conc.), warm : HCl gas, which turns blue litmus paper red.

NOTE.—The conc. H_2SO_4 test can usually be applied either to the solid salt or to its sol.

WET TESTS.—Diss. ·1 gm. NaCl in 5 c.c. of aq.

$AgNO_3$: white curdy ppt. of AgCl which darkens on exposure to light. Insol. in HNO_3, sol. in NH_4OH, KCy, etc. Fuses to a horny mass.

H_2SO_4 and MnO_2, warm : Cl, which bleaches litmus paper.

$K_2Cr_2O_7$ (about 0·1 gm. in powder) and 2 c.c. of H_2SO_4, on warming with a dry chloride evolve red-brown vapours of chromyl chloride (CrO_2Cl_2) which condense to a dark red liquid.

Hypochlorous Acid. HClO.

DRY TESTS.—Hypochlorites when heated are converted into chlorides and chlorates. The CO_2 in the air decomposes them with evolution of chlorine.

WET TESTS.—Diss. ·1 gm. NaClO in 6 c.c. of cold aq., or pass Cl into 6 c.c. cold dil. NaOH sol.

Litmus, Indigo, etc., are bleached by aqueous solutions of hypochlorites.

HCl (dil.) : Cl, recognised by its odour and colour.

$MnSO_4$: is oxidized to brown MnO_2, H_2O.

$NiSO_4$: is oxidized to black $Ni(OH)_3$.

$Pb(C_2H_3O_2)_2$: white ppt. of $PbCl_2$, which gradually becomes yellow, orange and finally brown, due to its conversion into lead peroxide.

Chloric Acid. $HClO_3$.

DRY TESTS.—1. On ignition alkaline chlorates fuse and evolve oxygen, or a mixture of O and Cl. They deflagrate on char. Diss. the residue in aq., add $AgNO_3$ sol. : white ppt. of AgCl. 2. When rubbed or heated with oxidizable substances, *e.g.*, C, S, P, sulphides, or cyanides, they explode violently, also when H_2SO_4 is added to such mixtures, or warmed with a chlorate; due to ClO_2.

H_2SO_4, conc. heated with a small fragment of $KClO_3$: sharp detonation. [CAUTION. Use only one small fragment of $KClO_3$, about ·003 gm. is sufficient.]

HCl : Cl and ClO_2 evolved.

WET TESTS.—Diss. ·1 gm. $KClO_3$ in 3 c.c. aq. All the chlorates are soluble.

$AgNO_3$: no ppt.

H_2SO_4, conc. : ClO_2 (a greenish-yellow gas) is evolved and the solution becomes orange coloured, on warming : violent explosion.

Indigo (and 2 drops of H_2SO_4) becomes bleached.

Perchloric Acid. $HClO_4$.

Perchlorates are more stable than chlorates; they are decomposed by hot conc. **H_2SO_4**, but not by the cold acid.

HCl or **HNO_3** : no action.

Hydrobromic Acid. HBr.

DRY TESTS.—Most bromides, like chlorides and iodides, fuse without decomposition; also when mixed with CuO and heated in the inner flame bromides impart a vivid blue colour to the flame.

Add H_2SO_4 to a small crystal and warm : red vaps. of Br.

WET TESTS.—Diss. 0·1 gm. KBr in 4 c.c. aq.

$AgNO_3$: pale yellow, curdy ppt. of AgBr, insol. in HNO_3; difficultly sol. in NH_4OH, readily in KCy.

H_2SO_4 : HBr, Br and SO_2 evolved.

H_2SO_4 and MnO_2 warmed with a bromide : dense red vaps. of Br.

Cl aq. : brown colour due to the Br set free. Shake with $CHCl_3$ or CS_2 : brown sol.

Bromic Acid. $HBrO_3$.

DRY TESTS.—All bromates are decomposed on ignition, and like the chlorates deflagrate when mixed with oxidizable substances.

WET TESTS.—Diss. ·05 gm. $KBrO_3$ in 2 c.c. aq.

$AgNO_3$: white $AgBrO_3$, this with HCl gives off Br.

H_2SO_4 : bromic acid, which breaks up into H_2O, Br and O.

Hydriodic Acid. HI.

DRY TESTS.—Most iodides on ignition give off I, but the alkaline iodides and AgI do not.

WET TESTS.—Diss. ·1 gm. of KI in 9 c.c. aq. All the iodides are sol. in acids except AgI.

$AgNO_3$: pale yellow AgI, nearly insol. in NH_4OH and in dil. HNO_3. Sol. in KCy, KI, NaCl, $Na_2S_2O_3$ and in HCl.

$Pb2C_2H_3O_2$: yellow PbI_2, sol. in hot aq., redeposited on cooling.

$HgNO_3$: greenish ppt., HgI.

$HgCl_2$: yellow ppt. of HgI_2 changing to scarlet, sol. in KI and in $HgCl_2$.

H_2SO_4 conc. : deep brown sol., due to I ; on warming yields purple vapours.

H_2SO_4 and MnO_2 : purple vapours of iodine.

Cu_2SO_4 : grey CuI. The cuprous sulphate, Cu_2SO_4, can be prepared by adding SO_2, $FeSO_4$, or Na_2SO_3 to $CuSO_4$. Chlorides and bromides do not precipitate $CuSO_4$.

Cl aq. (or **Br aq.**, or **dil. HCl** and a drop of **KNO_2** sol.) and **starch** sol. : blue colour.

Cl aq. (or **Br aq.**) and **CS_2** or **chloroform** : purple solution.

Iodic Acid. HIO_3.

DRY TESTS.—All iodates decompose on ignition, some lose O and are converted into iodides, and others give off both I and O. They explode when heated with charcoal and other combustible substances.

WET TESTS.—Diss ·1 gm. of KIO_3 in 5 c.c. aq. Only the alkali iodates are sol. in water.

$BaCl_2$: white ppt. of $Ba(IO_3)_2$, difficultly sol. in dil. HNO_3.

$AgNO_3$: white ppt. of $AgIO_3$, sparingly sol. in dil. HNO_3, but readily in NH_4OH.

SH_2 : ppt. of S.

H_2SO_3 : ppt. of iodine and S.

KI, starch sol. and **acetic acid** : blue "iodide of starch." Used as a test for the presence of iodate in iodides.

Sulphuric Acid. H_2SO_4.

DRY TESTS.—**Blowpipe.** Fuse the sulphate with pure Na_2CO_3 on char. or on a charred match, in the reducing flame to convert the sulphate into Na_2S, place the melt or fused mass on a brightened coin and moisten; a brown or black stain will be produced. All sulphur compounds give this reaction.

WET TESTS.—Diss. ·1 gm. of Na_2SO_4 in 2 c.c. of aq.

$BaCl_2$: heavy white ppt. of $BaSO_4$, insol. in HNO_3 and NH_4OH. Dil. solutions require to stand for some time.

$Pb2C_2H_3O_2$: heavy white ppt. ($PbSO_4$) insol. in HNO_3, sol. in boiling conc. HCl, in KOH, $NH_4C_2H_3O_2$ and $Na_2S_2O_3$.

Free H_2SO_4 is recognised by evaporating it down on a water bath with a little cane sugar, or fragment of filter paper, which chars.

Insoluble sulphates (*e.g.*, $BaSO_4$). Boil with pure Na_2CO_3, or fuse with pure Na_2CO_3 on Pt foil, dissolve the residue in water, filter off the carbonates formed, and test the filtrate with $BaCl_2$ as above.

Sulphurous Acid. H_2SO_3.

DRY TEST.—On heating, some sulphites give off odour of burning S,(SO_2).

WET TESTS.—Diss. ·2 gm. of Na_2SO_3 in 6 c.c. aq.

$BaCl_2$: white ppt. of $BaSO_3$, soluble in strong HCl; if the ppt. is not entirely soluble in HCl some H_2SO_4 is present, filter off the $BaSO_4$ formed and to the filtrate add Cl water. If a second ppt. of $BaSO_4$ forms it is due to a sulphite which has been oxidised by the Cl to a sulphate. $BaSO_3$ becomes insol. in dil. HNO_3 from the formation of $BaSO_4$.

HCl (dil.) : SO_2 is evolved.

$AgNO_3$: white Ag_2SO_3, sol. in excess of Na_2SO_3 ; add a drop of H_2SO_4 and warm : metallic Ag.

$KMnO_4$ with a drop of **H_2SO_4** is reduced and decolourised (very delicate).

K_2CrO_4 sol. and 2 drops HCl : green colour.

$FeCl_3$: red colour ; on boiling : ppt. of brown basic salt. (Distinction from thio-sulphates.)

Thiosulphuric Acid. $H_2S_2O_3$.

Only known in combination.

Most thiosulphates are sol. in water.

DRY TESTS.—All thiosulphates are decomposed on ignition, some fuse and the S burns.

WET TESTS.—Diss. ·5 gm, $Na_2S_2O_3$ in 4 c.c. aq.

HCl, warm : SO_2 is evolved and S deposited.

$AgNO_3$: white ppt. of Ag thiosulphate ($Ag_2S_2O_3$), which quickly passes into black Ag_2S.

$FeCl_3$: violet colour which gradually fades.

Zn and **HCl** : SH_2 and ppt. of S, the nascent hydrogen generated reduces the $H_2S_2O_3$.

Hydrogen Sulphide (Sulphine). SH_2.

DRY TESTS.—1. **Ignition tube.** Many metallic sulphides heated in a bulb tube evolve SO_2 and yield a sublimate of free S. As_2S_3 and HgS sublime undecomposed.

2. **Roasting tube.** Heated in an **open** tube sulphides evolve SO_2.

3. On char. before the blowpipe : SO_2, and sometimes the flame of burning S.

WET TESTS.—Only the sulphides of the alkalies and of Sr and Ba are soluble in aq. ; Ca and Mg sulphides are sparingly soluble. Diss ·1 gm. Na_2S in 3 c.c. aq. and filter off the separated S.

HCl (dil.) : SH_2 gas evolved from above and from FeS, MnS, and ZnS ; on heating the sol. S separates. SH_2 can be recognised by its odour.

[NOTE. All the sulphides except those of Ag, Hg, Pt, Au and As evolve SH_2 with strong HCl].

Paper moistened with **Pb. acetate** sol. is blackened by SH_2 gas.

HNO_3 (strong) : converts Bi_2S_3, CuS, Ag_2S, PbS, As_2S_3 into sulphates and free S. SnS_2, Sb_2S_3 and As_2S_3 are converted into SnO_2, Sb_2O_4 and H_3AsO_4.

$SbCl_3$ sol. : orange Sb_2S_3.

Na. nitroprusside $Na_2FeNOCy_5$: purple colour with even traces of soluble sulphides, no colour with free SH_2.

[NOTE. To prepare $Na_2FeNOCy_5$, warm 5 c.c. of strong HNO_3 with ·5 gm. of K_3FeCy_6 in a test tube, dilute and neutralize with Na_2CO_3.]

Nitric Acid. HNO_3.

DRY TESTS.—On ignition most nitrates fuse and give off red fumes; they deflagrate when heated with oxidizable substances such as organic matter, charcoal, sulphides and alkaline cyanides.

WET TESTS.—Diss. ·2 gm. of $NaNO_3$ in 5 c.c. aq.

Cu foil and **H_2SO_4**, warm : red fumes of NO_2.

$FeSO_4$, add a crystal and 4 drops **conc. H_2SO_4** : brown colouration around the crystal, due to the evolution of NO and its solution in $FeSO_4$.

H_2SO_4 conc. ·5 c.c. then carefully pour a solution of **$FeSO_4$** on to the top : brown ring.

Diss. a particle of **Brucine** in one drop of conc. H_2SO_4 on a watch glass, add a drop of $NaNO_3$ sol. and stir : deep red colour.

Indigo and **H_2SO_4 (conc.)** : the blue colour changes to yellow **(isatin)**.

To detect **free nitric acid** in the **presence of a nitrate,** warm the mixture on a water bath with white wool or silk or with small pieces of quill ; a yellow stain shows the presence of free nitric acid.

Nitrous Acid. HNO_2

DRY TEST.—On ignition nitrites fuse, yield oxides, and give off N and O. Mixed with oxidizable bodies they deflagrate like the nitrates.

WET TESTS.—Diss. ·1 gm. of KNO_2 in 6 c.c. aq.

$FeSO_4$ and **H_2SO_4** (conc.) : a brown colour. (See HNO_3).

$HgNO_3$ is reduced to metallic Hg on warming.

Indigo in H_2SO_4 : yellow isatin.

KI and **starch** solution and **acetic acid** : blue colour ; sensitive to 1 in 10 millions. (See iodides).

Sulphanilic acid and **napthylamine**. Diss. equivalent weights of these in H_2SO_4 and add 1 c.c. of the mixture to 1 c.c. of the above nitrite sol. diluted to 100 c.c. : rose colour. It is said to detect 1 of HNO_2 in 10,000,000 of aq.

Meta-phenylenediamine hydrochloride and **HCl** one drop : yellow to brown (1 in 250,000).

To detect nitrates in the presence of nitrites. Destroy the nitrite by boiling with **urea** and **H_2SO_4**, or with **NH_4Cl**, when the nitrate may be detected by the $FeSO_4$, or Cu tests.

Silicic Acid, H_4SiO_4. Silica, SiO_2.

DRY TESTS.—**Blowpipe.** Infusible; with Na_2CO_3 : clear glass. Silicates fused in microcosmic bead : floating skeleton of SiO_2.

Silica and all silicates except those of Na and K are practically insol. in water.

WET TESTS.—Fuse ·2 gm of SiO_2 in ·5 gm. of Na_2CO_3 on Pt foil : clear glass of Na_2SiO_3; diss. the result in 10 c.c. boiling aq., and use it for the following experiments.

HCl (dil.) when neutral : ppt. of gelatinous H_4SiO_4; evaporate 5 c.c. to dryness, the dry product (SiO_2) is now insol. in water and in acids.

$\mathbf{AgNO_3}$: orange ppt. of Ag_2SiO_3, sol. in acids and NH_4OH.

$\mathbf{NH_4Cl}$ and $\mathbf{(NH_4)_2CO_3}$: ppt. of H_4SiO_4.

HF decomposes most silicates; pass the resulting SiF_4 into aq. : gelatinous H_4SiO_4.

Silicates which are insoluble in acids. Finely powder and fuse the silicate with Na_2CO_3 and K_2CO_3 on Pt foil; extract the Na and K silicates with hot water, filter off the metallic carbonates; acidify the filtrate with HCl and evaporate to dryness, extract with hot aq., residue : SiO_2. Silica is usually detected in the examination for bases.

Hydrofluosilicic Acid (Fluosilicic or Silicofluoric Acid), H_2SiF_6.

DRY TESTS.—Silicofluorides on ignition : fluorides and SiF_4. Heated with H_2SO_4, HF is evolved.

WET TESTS.—Diss. ·1 gm. of $(NH_4)_2SiF_6$ in 4 c.c. aq., or use a solution of the acid itself.

$\mathbf{BaCl_2}$: crystalline ppt. of $BaSiF_6$. Hastened by adding an equal vol. of alcohol.

$\mathbf{SrCl_2}$: no ppt.

KCl : gelatinous K_2SiF_6.

$\mathbf{NH_4OH}$: gelatinous H_4SiO_4.

Boric acid, H_3BO_3. Metaboric Acid, HBO_2. Pyroboric Acid, $H_2B_4O_7$.

All the alkali borates are readily soluble in aq., the others sparingly; all are soluble in acids.

DRY TESTS.—**Blowpipe.** (*a*) Many borates intumesce (*i.e.*, boil up) when heated, and yield a colourless glass. (*b*) Mixed with $KHSO_4$ and fused on Pt. wire : green flame. (*c*) For traces of boron mix the substance with $KHSO_4$ and CaF_2, and fuse on Pt wire : green colour, due to BF_3.

WET TESTS.—Diss. ·1 gm. of borax ($Na_2B_4O_7.10H_2O$) in 6 c.c. aq.

H_2SO_4 conc. : scales of H_3BO_3 (from strong solutions only).

Turmeric paper dipped into the solution : brown colour.

Curcumine (or turmeric) and **oxalic acid.** Dry on water bath : magenta colour, on adding NaOH it changes to blue. If not already free, set the boric acid free by two drops of HCl or H_2SO_4.

$BaCl_2$: white ppt. of BaB_2O_4 forms slowly; sol. in acids.

$AgNO_3$: white (Ag_3BO_3) sol. in HNO_3 and in NH_4OH, sol. becomes black on boiling.

H_2SO_4 conc. or **glycerol,** make into a thin paste with a **borate** and warm, add to a little spirit and ignite : green edged flame.

Phosphoric Acid (Orthophosphoric Acid). H_3PO_4.

DRY TESTS.—**Blowpipe.** Normal metallic phosphates are not decomposed on ignition; those containing H lose H_2O and are converted into pyro and metaphosphates. Most phosphates are decomposed on fusion with K_2CO_3 and Na_2CO_3, the phosphates of Ba, Sr and Ca are only partly decomposed; in the case of $AlPO_4$, add SiO_2 to the fusion mixture. Most dry metallic phosphates, when heated with Mg or Na in a tube, or fused by the blowpipe with dry Na_2CO_3 on char., or with the match test, are reduced to phosphides, and these emit phosphine (PH_3) when moistened with water. Phosphates heated with $Co2NO_3$: blue colour.

On heating orthophosphoric acid it loses water and yields pyrophosphoric acid, and finally metaphosphoric acid.

WET TESTS.—Diss. ·1 gm. of Na_2HPO_4 in 6 c.c. aq.

$BaCl_2$: white ppt. of $BaHPO_4$, sol. in HNO_3 and in HCl, difficultly sol. in NH_4Cl.

$CaCl_2$: white ppt. of $Ca_3P_2O_8$, sol. in $HC_2H_3O_2$.

$MgCl_2$ + NH_4Cl + NH_4OH : crystalline ppt. of $MgNH_4PO_4.6H_2O$, especially on stirring or shaking; insol. in NH_4OH, sol. in acetic acid. (See arsenic acid).

$AgNO_3$: yellow ppt., Ag_3PO_4, sol. in HNO_3 and in NH_4OH.

$(NH_4)_2MoO_4$ in HNO_3 conc. and warm : yellow crystalline ppt. of ammonium phospho-molybdate, $(MoO_3)_{12}(NH_4)_3PO_4$. (?)

$FeCl_3$: yellowish gelatinous ppt. of $FePO_4$, somewhat sol. in excess of $FeCl_3$, sol. in HCl. Arseniates also give a yellow ppt., hence if present they must be reduced by SO_2 and removed by SH_2. (See also "phosphates" table.)

Pyrophosphoric Acid ($H_4P_2O_7$) and Metaphosphoric Acid (HPO_3).

Both give white ppts. with $AgNO_3$, metaphosphates (with acetic acid) coagulate albumen, pyrophosphates do not.

They do not give ppts. with $(NH_4)_2MoO_4$ in the cold, but on boiling they are converted into orthophosphoric acid, which gives a ppt.

[NOTE.—Pyrophosphates and metaphosphates are converted into orthophosphates during the process of analysis, hence they must be sought for by special methods.]

Phosphorous Acid. H_3PO_3.

DRY TESTS.—Phosphites decompose and ignite when heated on Pt. foil. Heated in a tube they evolve H and PH_3, and are converted into phosphates. Phosphites of the alkalies are soluble in water.

WET TESTS.—Diss. ·1 gm. Na_2HPO_3 in 4 c.c. aq.

$AgNO_3$: metallic silver; the reduction is aided by NH_4OH and warming.

$HgCl_2$: HgCl and Hg. slow clouding

Zn and HCl : H and PH_3, the gas burns with a green colour and blackens filter paper moistened with $AgNO_3$, due to the formation of Ag_3P and metallic Ag.

SO_2 is reduced to S, and SH_2 is evolved. The phosphite is oxidized to phosphate.

Hypophosphorous Acid. H_3PO_2

DRY TEST.—On ignition hypophosphites evolve PH_3, and are converted into pyrophosphates, $M'_4P_2O_7$.

WET TESTS.—Diss. ·1 gm. NaH_2PO_2 in 5 c.c. of aq.

H_2SO_4 is reduced to H_2SO_3 and S (on warming).

$AuCl_3$, $AgNO_3$ and $CuSO_4$ are reduced to metals. PO_2 evolving PH_3 when ignited

Zn and H_2SO_4 : H and PH_3, with garlic odour.

Carbonic Acid. H_2CO_3.

DRY TESTS.—On ignition, alkali carbonates fuse without decomposition, at high temperatures they volatilize; the others decompose into CO_2 and oxide of the metal, or CO_2, O and the metal.

WET TESTS.—Diss. ·1 gm. Na_2CO_3 in 5 c.c. aq.

HCl : effervescence, a rod or tube which has been dipped into lime water and lowered into the escaping gas becomes coated with $CaCO_3$; the gas extinguishes a taper. Native $MgCO_3$, $CaMg(CO_3)_2$ and $FeCO_3$ are very slowly decomposed by cold HCl.

$BaCl_2$: white ppt. of $BaCO_3$ which dissolves in dil. HCl with effervescence.

ORGANIC ACIDS.

Hydrocyanic Acid. HCN or HCy.

DRY TESTS.—**Blowpipe.** (*a*) KCy and NaCy fuse when heated and gradually oxidize to cyanates (M'CNO); cyanides of the heavy metals are decomposed and cyanides of Au, Hg, Ag, etc., yield free cyanogen $(CN)_2$ or Cy_2 and brown paracyanogen Cy_n; Na, K, Hg and Ba cyanides are sol. in aq., those of Ag, Cd, Co, Cu, Ni and Zn are not. (*b*) Fuse with a particle of $Na_2S_2O_3$ in a Pt ring until the S flame appears, place the bead in a sol. of $FeCl_3$: a red colour of $Fe(CyS)_3$. (*c*) Fuse a cyanide with KOH : NH_3.

WET TESTS.—Diss. ·1 gm. KCy in 6 c.c. aq.

The cyanides of the alkalies emit the odour of HCy, from the action of CO_2 and H_2O in the air.

HCl (dil.) : HCy. **Do not inhale, as HCy is intensely poisonous.** Test the odour with great care by wafting the fumes towards the nose with the hand. Certain double cyanides also evolve HCy, *e.g.*, KCy,AgCy + HNO_3 = AgCy + HCy + KNO_3; but other double cyanides do not, *e.g.*,

$$K_4FeCy_6 + 4HCl = H_4FeCy_6 \text{ (Ferrocyanic acid)} + 4KCl.$$
$$2K_3FeCy_6 + 6HCl = 2H_3FeCy_6 \text{ (Ferricyanic acid)} + 6KCl.$$
$$2K_3CoCy_6 + 6HCl = 2H_3CoCy_6 \text{ (Cobalticyanic acid)} + 6KCl.$$

$AgNO_3$: white curdy ppt. of AgCy, insol. in dil. HNO_3; sol. in NH_4OH, $Na_2S_2O_3$ and in excess of KCy. On ignition : metallic Ag (AgCl fuses). If AgCy and AgCl are both present, wash, ignite, dissolve out the metallic Ag by HNO_3, and add HCl : ppt. of AgCl. Add dil. **H_2SO_4** to a cyanide in a watch glass and invert over it another watch glass moistened inside with yellow NH_4SH, in a few minutes NH_4CNS is formed, evaporate this nearly to dryness over a water bath and add a drop of $FeCl_3$ sol. : a blood red colour.

$HgNO_3$: grey ppt. of Hg.

$FeSO_4$, $FeCl_3$ and HCl, on warming : ppt. of Prussian blue.

$NaNO_2$ and $FeCl_3$ and dil. H_2SO_4 until the colour is yellow; warm gently, cool, add NH_4OH and filter, then one drop NH_4SH : violet colour ; due to Na nitroprusside.

Cyanic Acid (Carbimide). HCyO.

Pot. cyanate, KCNO, is formed by the oxidation of KCy. KCyO deliquesces and smells of NH_3.

$$KCNO + 2H_2O = KHCO_3 + NH_3.$$

The cyanates of the alkalis, alk. earths and some others are sol. in aq., the solutions decompose and evolve NH_3. On warming the sol. of Am. cyanate it changes into urea, NH_4CyO : $(NH_2)_2CO$.

DRY TESTS.—On ignition, many of the cyanates of the heavy metals evolve CO_2 and form cyanides.

WET TESTS.—Diss. ·05 gm. KCyO in 2 c.c. aq.

HCl : pungent odour of HCyO, irritates the eyes.

$AgNO_3$: white ppt., AgCyO, sol in NH_4OH and in dil. HNO_3.

Hydroferrocyanic Acid. $H_4FeC_6N_6$ or H_4FeCy_6.

DRY TESTS.—On strong ignition some fuse and yield N, M'Cy, Fe, iron carbide, and some M'CyO; thus $K_4FeCy_6 : 4KCy + 2C + Fe + N_2$. The alk. ferrocyanides are sol. in aq., those of Ba, Sr, and Ca, sparingly sol.; most of the others are insol. in aq., and some are insol. in acids.

WET TESTS.—Diss. ·1 gm of crystallized K_4FeCy_6 in 7 c.c. aq.

H_2SO_4 (conc.) : CO evolved.

H_2SO_4 (dil.) : HCy evolved.

HCl (conc.) : white ppt. of H_4FeCy_6, changes to blue.

$AgNO_3$: white ppt. Ag_4FeCy_6 sol. in KCy but insol. in dil. HNO_3 and in NH_4OH.

$CuSO_4$, in excess : chocolate ppt. of Cu_2FeCy_6.

$FeSO_4$: pale blue ppt. of pot. ferrous ferrocyanide $K_2Fe(FeCy_6)$ which rapidly oxidizes to ferric ferrocyanide (Prussian blue) $Fe_4(FeCy_6)_3$.

$FeCl_3$: Prussian blue, insol. in dil. mineral acids, but sol. in oxalic acid (: blue ink) and ammonium tartrate (: violet ink). [NOTE. This is also a test for tartrates.] If insufficient $FeCl_3$ is added this ppt. is sol. in aq., known as soluble Prussian blue, also used as a blue ink. Prussian blue is decomposed by alkalis.

$$Fe_4(FeCy_6)_3 + 12KOH = 3K_4FeCy_6 + 4Fe(OH)_3$$

i.e., the cathion iron is precipitated but not that in the anion.

Hydroferricyanic Acid. $H_3Fe(CN)_6$ or H_3FeCy_6.

Ferricyanides can be obtained by oxidising ferrocyanides with Cl, etc.

DRY TESTS.—On heating, K_3FeCy_6 evolves N and Cy, and leaves a residue of paracyanogen, carbon, iron carbide and Prussian blue. The alkali ferricyanides are sol. in water, most of the others are not.

WET TESTS.—Diss. 0·1 gm. of K_3FeCy_6 in 3 c.c .aq., or add Cl water to 3 c.c. K_4FeCy_6 solution.

$AgNO_3$: reddish ppt. of Ag_3FeCy_6, sol. in NH_4OH and in KCy, insol. in dil. HNO_3.

$FeSO_4$: blue ppt. of ferrous ferricyanide, $Fe_3(FeCy_6)_2$ (Turnbull's blue), decomposed by KOH.

$FeCl_3$: brown or green colour.

Thiocyanic Acid (Sulphocyanic Acid). HCNS or HCyS.

DRY TESTS.—KCyS on ignition is converted into KCyO, K_2SO_4 and SO_2. The thiocyanates of the heavy metals evolve CS_2, N and CN, and leave a metallic sulphide.

WET TESTS.—Dissolve ·01 gm. NH_4CyS or KCyS in 3 c.c. aq.

$AgNO_3$: white curdy ppt. of AgCyS, sol. in NH_4OH, but insol. in dil. acids.

$CuSO_4$ (2 drops) : black ppt. of $Cu(CyS)_2$. If the $CuSO_4$ is in excess there is no ppt.

$FeCl_3$: blood red coloured sol. of $Fe(CyS)_3$, on adding **Zn** to the red sol. SH_2 is evolved. $HgCl_2$ discharges this colour, HCl does not.

Formic Acid. H.COOH.

Fuming liquid, with pungent odour, boils 99° C., mixes with H_2O, alcohol, and ether.

Its salts are readily sol., except Pb formate; the salts (and the free acid) are strong reducing agents.

DRY TESTS.—Solid formates when heated char slightly, and evolve CO and CO_2.

WET TESTS.—Diss. ·01 gm. Na formate, $NaCHO_2$, in 7 c.c. aq.

H_2SO_4, dil. : formic acid is evolved, recognised by its odour and by its blackening paper moistened with $AgNO_3$.

H_2SO_4 conc. decomposes formic acid and the formates, and CO is evolved.

H_2SO_4 and alcohol : formic ether (odour of rum).

$AgNO_3$, warm : black ppt. of Ag.

$HgCl_2$, warm : white ppt. of HgCl or of grey metallic Hg.

$FeCl_3$: red colour (like acetates) destroyed by the addition of HCl ; on boiling, basic ferric formate is precipitated and the liquid becomes colourless.

$KMnO_4$ sol., is reduced by formic acid.

Acetic Acid. CH_3.COOH.

A colourless pungent acid liquid, crystallizes at 16·5° and boils at 118°, its vapour burns with a bluish flame. Mixes with water, alcohol, and ether in all proportions.

DRY TESTS.—Acetates on ignition give off acetone and other inflammable vapours and leave a carbonate, oxide, or metal.

Dry acetates heated with a little As_2O_3 (use ·01 gm.), give off Cacodyl $As(CH_3)_2$ (or cacodyl oxide, $(CH_3As)_2O$), recognised by its offensive odour. [N.B.—**This is extremely poisonous. Caution.**—Never apply the test tube to

the nose when testing by odour, always waft the vapour from the test tube towards the nose by the hand, or cover the mouth of the test tube with a piece of filter paper, remove the paper after a few moments and ascertain whether it has acquired any odour].

WET TESTS. Diss. ·2 gm. Na acetate ($NaC_2H_3O_2$) in 4 c.c. aq.

H_2SO_4 (either dil. or conc.) : odour of "vinegar," *i.e.*, of acetic acid.

H_2SO_4 and alcohol on warming : ethereal odour of ethyl acetate.

$AgNO_3$, in strong solutions : white crystalline Ag acetate; not reduced on boiling. (Distinction from formic acid.)

$FeCl_3$ in neutral sols. : dark red colour, destroyed by HCl ; on boiling a ppt. of basic ferric acetate forms and the solution becomes colourless.

Propionic Acid. $C_2H_5.COOH$.

Has the odour of rancid butter and of acetic acid. Occurs in sour cocoanut milk, oil of amber, and in certain wines when the fermentation has gone too far. Propionates are sol. in aq. If the free acids (formic, acetic, and propionic) are evaporated to dryness with PbO and extracted with cold aq. and filtered, the Pb acetate and Pb formate will be found in the residue and the Pb propionate (basic) in the solution.

Butyric Acids. $C_3H_7.COOH$.

The normal acid, $C_3H_7.COOH$, has a strong and characteristic odour ; b.p. 163° C. The iso-butyric acid $(CH_3)_2CH.COOH$, boils at 150°, otherwise it closely resembles the former. Both are sparingly sol. in water. Can be separated from aqueous solution by agitating with ether and then evaporating.

All the butyrates are sol. in H_2O.

WET REACTIONS.—Diss. ·1 gm. of Na butyrate in 6 c.c. aq.

H_2SO_4, warm : odour of butyric acid.

H_2SO_4 and alcohol : ethyl butyrate, $C_2H_5.C_4H_7O_2$, odour of pine apples (best test).

$AgNO_3$: white ppt. of $AgC_4H_7O_2$.

$FeCl_3$: reddish brown sol.

Cu acetate, with strong solutions : bluish-green oblique crystals.

Pb acetate : white ppt., becoming oily on warming.

Oxalic Acid. $(COOH)_2$.

Crystallizes in rhombic prisms $(COOH)_2.2H_2O$, which lose H_2O and effloresce. Intensely poisonous. The normal oxalates of the alkalis are sol. in aq., most of the others are not.

DRY TESTS.—On heating in a tube it yields aq. and sublimes, part is decomposed into CO, CO_2 and formic acid.

On ignition alk. oxalates give off CO, blacken slightly and leave a carbonate; oxalates of the alk. earths give off CO and CO_2, and leave a carbonate which at high temps. is converted into M″O.

H_2SO_4 (conc.), warm, oxalic acid and oxalates decompose into CO and CO_2 without blackening. Test for CO_2 by CaO_2H_2 on the end of a glass rod.

WET TESTS.—Diss. ·2 gm. of $(NH_4)_2C_2O_4$ in 4 c.c. aq.

$CaCl_2$: white ppt. of CaC_2O_4, sol. in HCl or HNO_3, almost insol. in KOH, NH_4OH, oxalic and acetic acids.

$SrCl_2$, with neutral oxalates : a white ppt. of SrC_2O_4, insol. in acetic acid and in boiling aq. (Distinction from tartaric and citric acids.)

$AgNO_3$: white ppt. of $Ag_2C_2O_4$, sol. in dil. HNO_3 and NH_4OH.

$KMnO_4$ (add H_2SO_4) is reduced and decolourized on warming. N.B.—Use a very weak sol. of $KMnO_4$.

Tartaric Acid. $(CH.OH)_2(COOH)_2$.

Large colourless crystals, very sol. in aq., sol. in alcohol. The normal salts of the alkalis are readily sol. in aq., but the acid salts of K and NH_4 are only slightly soluble.

DRY TESTS.—On heating, tartaric acid and tartrates evolve odour of caramel; the tartrates of the alkalis and alk. earths leave a carbonate mixed with carbon, the tartrates of the heavier metals leave the metal or its oxide mixed with carbon.

H_2SO_4 (conc.), warm, blackens, with evolution of CO, CO_2, and SO_2.

WET TESTS.—Diss. ·5 gm. tartaric acid in 5 c.c. aq.

KCl, stir and let stand for some time : crystalline ppt. of $KHC_4H_4O_6$ with an acid tartrate or free tartaric acid, but boric acid prevents the precipitation; insol. in acetic acid, readily sol. in HCl, HNO_3, H_2SO_4, alkalis and alk. carbonates.

CaO_2H_2 (in excess) with free tartaric acid : white ppt. of Ca tartrate, sol. in NaOH and acetic acid.

FOR NEUTRAL TARTRATES.—Diss. ·5 gm. $NH_4KC_4H_4O_6$ in 5 c.c. aq.

$CaCl_2$, with neutral sols. of tartrates : white ppt. of $CaC_4H_4O_6$, stir and let stand; sol. in free tartaric acid.

$AgNO_3$: white curdy ppt. of $Ag_2C_4H_4O_6$, sol. in excess of the tartrate, in NH_4OH and in HNO_3.

Partially dissolve some of the $Ag_2C_4H_4O_6$ ppt. in dil. NH_4OH, add a fragment of $AgNO_3$, immerse the test tube in a beaker of warm water (about

60° C) for 10 to 20 minutes; the Ag is reduced and forms a mirror on the test tube. A little free NaOH is said to hasten the formation of the mirror. N.B.—Clean the test tube before using with NaOH and distilled aq.

TO DISTINGUISH BETWEEN CITRIC AND TARTARIC ACIDS.

Resorcin and about 2 c.c. conc. H_2SO_4 added to a very small quantity of a solid tartrate or tartaric acid, and carefully warmed : bright red colour.

Pyrogallol, instead of resorcin : purple.

$FeSO_4$, a few drops of **H_2O_2** and an excess of **NaOH** : blue to purple colour. Citric acid does not give the above colour reactions.

Succinic Acid. $C_2H_4(COOH)_2$.

Crystallized; readily sol. in water, alcohol, and ether, insol. in chloroform. Benzoic acid is soluble.

DRY TESTS.—When heated in a tube it yields water and the anhydride sublimes, emits irritating vapours and causes coughing.

Solid succinates when warmed with $KHSO_4$ yield succinic acid in oily drops, which crystallize on cooling.

WET TESTS.—Diss. ·05 gm. of ammonium succinate in 3 c.c. aq.

$BaCl_2$: ppt. of Ba succinate on stirring. Add alcohol if the solution be dilute. Benzoates do not yield a ppt. with $BaCl_2$.

$FeCl_3$: pale brownish ppt. of basic ferric succinate, sol. in acids.

$Pb(C_2H_3O_2)_2$; white amorphous ppt., sol. in excess of either the succinate or Pb acetate; Pb succinate crystallizes out on standing.

Malic Acid. $C_2H_3(OH)(COOH)_2$.

Crystallized ; readily sol. in aq. and in alcohol.

DRY TESTS.—Heated in a tube it yields aq. and a crystalline sublimate of maleic and fumaric acids; at higher temperatures it emits odour of caramel, chars and evolves CO and CO_2.

WET TESTS.—Diss. ·05 gm. of Na malate in 3 c.c. aq.

$CaCl_2$: white ppt. of $CaC_4H_4O_5,3H_2O$, on boiling or adding 2 vols. alcohol.

Pb acetate : a white ppt., which fuses on warming the liquid.

$AgNO_3$: a white ppt., becoming grey on boiling.

Citric Acid. $C_3H_4(OH)(COOH)_3$.

Crystallized; readily sol. in aq. and in alcohol.

DRY REACTIONS.—On heating in a tube citric acid yields aq. of crystallization, fuses and gives off irritating fumes (aconitic and citraconic acids and anhydrides) and leaves a residue of carbon. Citrates of the alkalis and alk. earths leave a carbonate.

WET TESTS.—Diss. ·5 gm. $Na_3C_6H_5O_7$ in 5 c.c. aq.

CaO_2H_2 : a white ppt. of Ca citrate, on boiling or long standing. (Difference between citric and tartaric acids).

$CaCl_2$: a white ppt. on long standing or boiling, in neutral or alk. sols.; insol. in NaOH, but sol. in NH_4 salts and in acids.

$AgNO_3$: white ppt. of $Ag_3C_6H_5O_7$, sol. in NH_4OH, the sol. on boiling is reduced to metallic Ag (grey or black) but does not form a mirror. (See tartaric acid.)

H_2SO_4 (conc.) on warming, CO and CO_2 are evolved; on boiling, the sol. slowly darkens and SO_2 is evolved.

Lactic Acids.

(*a*) **Fermentation or ordinary lactic acid,** $CH_3.CH.OH.COOH.$, optically active.

(*b*) **Sarco-lactic,** optically inactive.

(*c*) **Ethene-lactic acid** : $CH_2OH.CH_2.COOH$.

All three are syrupy inodorous liquids; sol. in aq., alcohol and ether.

DRY TESTS.—At 150°, *a* and *b* lactic acids lose water and emit irritating vapours of the anhydrides.

WET TESTS.—Diss. ·2 gm. Na lactate in 5 c.c. aq.

H_2SO_4 (dil.) warm : acetaldehyde and formic acid.

H_2SO_4 (conc.) : CO evolved.

Fehling's solution : not reduced.

$Ca_3(PO_4)_2$ (if recently precipitated) is dissolved by lactic acid.

$AgNO_3$ is reduced by boiling with lactic acid.

AROMATIC SERIES.

Benzoic Acid, $C_6H_5.COOH$.

Crystallized in needles or plates, slight aromatic odour. Sparingly sol. in cold aq., more sol. in hot, readily in alcohol, ether, chloroform, alkalis, etc. Most benzoates are sol. in aq.

DRY TESTS.—Melts at 121·4° C., volatilizes with irritating fumes. Yields sublimate of feathery crystals; burns with smoky flame. Benzoic acid and solid benzoates heated with CaO yield benzene, C_6H_6.

WET TESTS.—Diss. ·05 gm. Na benzoate in 5 c.c. aq.

H_2SO_4 : ppt. of white crystals (benzoic acid).

H_2SO_4 and alcohol, aromatic odour of benzoic ether, $C_2H_5.C_7H_5O_2$.

$FeCl_3$, in neutral sols. : buff ppt. of basic ferric benzoate, sol. in NH_4OH.

Pb acetate : flocculent ppt. of $Pb(C_7H_5O_2)_2.H_2O$, from fairly strong sols., sol. in Pb. acetate and in acetic acid.

H_2SO_4 and a fragment of **Mg** : odour of benzaldehyde, $C_6H_5.CHO$.

Salicylic Acid. $C_6H_4.OH.COOH$.

Crystallized; slightly sol. in cold, more sol. in hot aq., sol. in alcohol, ether and alkalis.

DRY TESTS.—Melts 155° C.; sublimes at higher temps., giving off phenol and CO_2. Distilled with CaO it yields phenol.

WET TESTS.—Diss. ·05 gm. of Na salicylate in 8 c.c. of aq.

H_2SO_4 (dil.) : crystalline ppt. of salicylic acid.

H_2SO_4 and methyl alcohol, warm : odour of oil of winter green (methyl salicylate).

H_2SO_4 (conc.) containing a few drops of 6 per cent. sol. of **KNO_2** yields on warming a permanent red colour (phenol : a **fleeting red**).

$NaNO_2$, two drops; **acetic acid**, four drops, and two drops of a dil. sol. of **$CuSO_4$**, boil : intense red colour.

$AgNO_3$: white ppt. of Ag salicylate (but not with the free acid).

$HgNO_3$ and HNO_3 (Millon's reagent), boil : red colour.

$FeCl_3$: violet colour, destroyed by alkalis and by mineral acids, not destroyed by acetic acid. (Distinction from phenol.)

Br water : white cryst. ppt. of tribromo-salicylic acid.

Gallic Acid. $C_6H_2(OH)_3.COOH$.

Yellowish acicular crystals; astringent taste; readily sol. in hot aq., sol. in alcohol, but sparingly in ether.

DRY TESTS.—On heating, it melts, CO_2 is evolved and pyrogallol sublimes.

H_2SO_4 (conc.), heat for two or three minutes : green sol., changing to claret or purple.

WET TESTS.—Boil ·02 gm. with 10 c.c. aq.

KOH, one drop, warm : bright green, changed to red by acids.

CaO_2H_2 : white ppt. changing through blue, green and violet to purple.

$FeSO_4$: pale blue colour.

$FeCl_3$ (dil.) : dark blue ppt., sol. in excess to a green solution.

Gelatin solution : no ppt.

It is distinguished from tannin by not being pptd. from aqueous sol. by acids, by cinchonine sulphate or by gelatine.

KCy : crimson, fleeting, but reappears on shaking.

$Pb2NO_3$: no ppt., compare tannic acid.

Fehling's solution : slowly reduced on boiling.

Tannic Acid (Digallic Acid, Gallotannic Acid, Tannin). $C_{14}H_{10}O_9$.

A buff or colourless powder, astringent taste, readily sol. in aq. and in alcohol, less sol. in ether. Acids precipitate it from aqueous solutions.

DRY TESTS.—On heating, tannin melts, blackens and yields H_2O, CO_2 and pyrogallol, the last condenses in yellowish drops and crystallizes on cooling.

H_2SO_4 : red colour.

WET TESTS.—Diss. ·02 gm. in 10 c.c. of aq.

NaOH in excess : a brown colour changing to red and then to yellow.

$FeCl_3$ with neutral sols. : a blue-black ppt. (ink).

Gelatin sol. : stringy ppt. (leather); gallic acid and pyrogallol do not coagulate gelatine.

KCy, shake : brown-red colour.

K_3FeCy_6 and NH_4OH : deep red colouration.

$Pb2NO_3$: white ppt. of Pb tannate. (Distinction from gallic acid and pyrogallol.)

Fehling's solution : reduced on boiling.

Pyrogallol, Pyrogallic Acid. $C_6H_3(OH)_3$.

Acicular colourless crystals ; poisonous. Melts 131°, boils 210° ; very sol. in water, alcohol, and ether, less sol. in chloroform and benzene.

DRY TESTS.—Heated in tube : black mass sol. in alkalis.

H_2SO_4 (conc.) : colourless sol., darkens on heating.

NaOH or KOH : solution, which rapidly darkens from absorption of oxygen.

WET TESTS.—Diss. ·02 gm. pyrogallol in 8 c.c. aq.

Tartaric acid, and 1 c.c. conc. **H_2SO_4,** warm : violet colour.

$FeCl_3$: green colour.

$FeSO_4$: bright blue colour.

CaO_2H_2 : purple colour, changing to brown.

Fehling's solution : red ppt. of Cu_2O.

$AgNO_3$: ppt. of metallic silver.

Formaldehyde, 2 drops, and 2 drops (conc.) **H_2SO_4** : white ppt., changing to red and purple.

Meconic Acid. $C_5H(OH)O_2(COOH)_2$.

Occurs in opium, as morphine meconate. Colourless rhombic prisms or in plates; readily sol. in alcohol and in hot water, sparingly sol. in cold aq.

DRY TESTS.—Heated in tube at 100° C. : water; at 120° : CO_2 and comenic acid ($C_6H_4O_5$) and at higher temps. : chars and emits odour of caramel.

WET TESTS.—Diss. ·001 gm. in C_2H_5OH and dilute to 6 c.c.

H_2SO_4 (conc.) : no change.

$AgNO_3$: pale yellow flocculent ppt. of Ag meconate, sol in NH_4OH.

$FeCl_3$: dusky purple colour; boil : a ppt. of basic ferric meconate.

$CaCl_2$, stir with glass rod : white silky ppt. of Ca meconate.

$Pb2C_2H_3O_2$: pale yellow ppt., insol. in acetic acid but sol in dil. HNO_3.

$CuSO_4$ and one drop of NH_4OH : green ppt.

Uric Acid. $C_5H_4N_4O_3$ or $(NH)_4C_2(CO)_3$.

Colourless crystals only slightly sol. in aq., insol. in alcohol and ether. Dissolves in KOH and NaOH, and in sols. of salts possessing an alkaline reaction.

DRY TESTS.—Heated in tube : does not melt, gives off NH_3, cyanic acid and HCy; cyanuric acid $(HCyO)_3$ is left. Heated with NaOH : NH_3 and NaCy; the residue gives Prussian blue with $FeSO_4$.

HNO_3 dissolves uric acid with effervescence, the sol. slowly evaporated to dryness on a W.B. and moistened with NH_4OH yields a crimson colour (**murexide**); NaOH changes this to purple.

H_2SO_4 : sol., does not char when heated; CO, CO_2 and SO_2 evolved.

WET TESTS.—Diss. ·01 gm. of Na urate in 1 c.c. NaOH.

HCl : white ppt. of uric acid.

Diss. ·01 gm. **uric acid** in 1 c.c. of Na_2CO_3 and place a drop on filter paper moistened with $AgNO_3$: black stain of reduced Ag.

Fehling's solution is reduced on warming.

Hippuric Acid. $C_9H_9O_3$.

Colourless prisms, bitter taste, acid reaction, slightly sol. in aq.

DRY TEST.—Heated with soda lime : NH_3 and benzene (C_6H_6) are evolved.

WET TESTS.—Diss. ·1 gm. of hippuric acid in dil. NH_4OH and boil off any excess of NH_4OH.

HCl : white ppt. of hippuric acid.

$FeCl_3$: flesh-coloured ppt.

$AgNO_3$: white ppt.

ALCOHOLS AND THEIR DERIVATIVES.

Methyl Alcohol (Wood Spirit). CH_3OH.

Colourless volatile liquid with a "spirituous" odour. Neutral, boils 60°, burns with non-luminous flame. Sp. gr. ·7972. When mixed with aq., heat is evolved and the volume contracts.

Use ·5 c.c. for each test.

H_2SO_4 (conc.), warm : dimethyl ether, recognised by its odour.

H_2SO_4 and Na formate : characteristic odour of methyl formate.

H_2SO_4 and ·01 gm. salicylic acid, warm : odour of oil of winter green (methyl salicylate).

H_2SO_4 (1 to 1 aq.) 5 c.c. and 1 gm. of $K_2Cr_2O_7$ and 5 c.c. methyl alcohol, distil from a test tube and test the distillate for formic acid.

Ethyl Alcohol (Spirit of Wine). $C_2H_5.OH$.

Colourless volatile liquid with characteristic odour and burning taste. Sp. gr. ·7938 at 15·5 ; boils 78·4° C., and burns with a non-luminous flame. When mixed with aq., heat is evolved and the vol. contracts ; mixes with ether and carbon bisulphide in all proportions. Dissolves many salts, oils, resins, etc.

Use ·5 c.c. for each test.

H_2SO_4 (conc.), warm : ether and ethene (C_2H_4) which burn with a luminous flame.

Aldehyde test. Add $K_2Cr_2O_7$ and H_2SO_4, warm : odour of aldehyde ($CH_3.CHO$) and the solution becomes green. Distil and test distillate for aldehyde by the rosaniline test.

H_2SO_4 (conc.), warm with strong alcohol and 1 gm. solid Na formate or Na acetate, or Na benzoate, etc., : the well-marked odour of formic, acetic, benzoic or other ether.

Iodoform test. Add ·5 c.c. Na_2CO_3 and sol. of iodine in KI, drop by drop, until the sol. retains a brown colour, warm to 60° C. ; on cooling, iodoform (CHI_3) separates in yellow six-rayed crystals ; the ppt. and sol. have a peculiar saffron-like odour. Aldehyde, acetone, acetic ether, etc., also yield iodoform.

KOH and CS_2 : yellow ppt. of pot. xanthate $KC_2H_5COS_2$, to this add **$CuSO_4$ and HCl** : a brown ppt. of copper xanthate, this becomes bright yellow and emits an offensive odour.

Hg_2NO_3, boil : white ppt. of $HgNO_3$, on adding NH_4OH it becomes grey or black. (Distinction from methyl alcohol.)

To detect **methyl alcohol in ethyl alcohol.**

Add **$K_2Cr_2O_7$** and **H_2SO_4** to oxidize them into formic and acetic acids; allow to stand for some time; distil, add a slight excess of **Na_2CO_3** to the distillate and concentrate; acidulate with acetic acid; add $AgNO_3$ and warm, if much metallic Ag is reduced (due to formic acid) then methyl alcohol is present.

Amyl Alcohol. $C_5H_{11}.OH$.

Colourless, oily liquid, strong odour, causes coughing; only slightly sol. in aq.; boils 132° C.

Use ·5 c.c. for each test.

H_2SO_4 (conc.), warm : reddish brown colour, next add ·5 c.c. glacial acetic acid and 1 c.c. $FeCl_3$ and warm again : a purple colour.

Na acetate, about ·1 gm. and 5 c.c. H_2SO_4, warm : odour of pears, due to the amyl acetate, intensified by pouring the mixture into water; this applies to the following test also.

$K_2Cr_2O_7$ about ·1 gm. and 5 drops **H_2SO_4**, warm : odour of amyl valerate $C_5H_{11}.C_4H_9O_2$.

Ether (Ethyl Oxide). $(C_2H_5)_2O$.

Mobile, colourless liquid, with a characteristic pleasant ethereal odour and sweet taste; very inflammable, burns with a luminous flame. (Alcohol burns with a non-luminous flame.) Mixtures of ether vapour and air explode violently on ignition. Sp. gr. ·736 at 0° C., boils 34·6° C. Very volatile, when placed on the skin it produces a feeling of great coldness.

Magenta (rosaniline acetate) is insol. in ether, if dry and free from alcohol.

Mixes with absolute alcohol and CS_2, but 1 part of ether requires 9 parts of aq. for its solution.

Dissolves fats, oils, resins, india rubber, phosphorus, iodine, sulphur, etc., readily.

Cl and Br act upon it readily.

Na and K do not act upon it.

Formaldehyde. H.CHO.

A gas with peculiar pungent odour. "Formalin" is a 40 per cent. sol. in aq. On evaporation over a W. B. : solid paraformaldehyde.

Use ·5 c.c. for each test.

$AgNO_3$ and NH_4OH, place the test tube in hot water : a silver mirror.

Fehling's solution, warm : ppt. of Cu_2O.

Magenta (or fuchsine) reduced **by SO_2,** has its colour restored by formaldehyde.

Pyrogallol (freshly-prepared solution) and excess of **strong HCl,** on standing : a white ppt. which gradually becomes magenta coloured.

Phenyl hydrazine hydrochloride, 3 drops of **Na nitroprusside,** (5 per cent. sol.), 10 drops **NaOH** (10 per cent. sol.) : blue colour.

K_3FeCy_6 : scarlet colour.

Acetaldehyde. CH_3.CHO.

Colourless mobile liquid, very volatile and inflammable; boils at 21°; choking odour; mixes with aq., alcohol and ether.

Use ·5 c.c. for each test.

$AgNO_3$ and NH_4OH, warm : a mirror of reduced silver.

Magenta, reduced by SO_2, has its colour restored by aldehyde.

KOH (conc.) warm, on standing : a yellow ppt. of aldehyde resin.

Fehling's solution : red ppt. of Cu_2O.

$NaHSO_3$: crystals of CH_3.CHO.$NaHSO_3$.

Pyrogallol and strong HCl, let stand : white ppt., which gradually becomes yellow. (See formaldehyde.)

Chloral Hydrate. CCl_3.CHO.H_2O.

Crystallized, greasy feel, disagreeable odour, bitter taste, melts readily, boils and condenses in drops which crystallize.

Dissolves readily in aq., alcohol and ether; rotates on the surface of water like camphor.

WET TESTS.—Diss. ·1 gm. in 5 c.c. of aq.

KOH : turbid, from separation of chloroform, which re-dissolves, but can be recognised by its odour.

$AgNO_3$ and NH_4OH (dil.) : odour of chloroform, and ppt. of metallic Ag.

Aniline and KOH in alcohol, warm : the offensive odour of phenyl isocyanide. (See chloroform.)

Fehling's solution, warm : ppt. of Cu_2O.

Acetone (Di-methyl Ketone). $CH_3.CO.CH_3$.

Colourless mobile inflammable liquid, with ethereal odour, mixes with aq., alcohol and ether; boils 56·5°.

Use ·5 c.c. for each test.

Iodine or Iodine in KI, then **Na_2CO_3** until the brown colour disappears, warm: iodoform (CHI_3) which crystallizes out on cooling.

$HgCl_2$, and NaOH drop by drop to excess, shake, and if necessary filter, the sol. contains HgO; acidify with HCl and add $SnCl_2$: ppt. of HgCl or Hg.

NH_4OH, and Iodine in KI drop by drop until a trace of black iodide of nitrogen forms, then warm carefully; on cooling CHI_3 crystallizes out. (Distinction from ethyl alcohol.)

$NaHSO_3$: crystals of $C_3H_6O,NaHSO_3$. Advantage is taken of this reaction commercially to purify acetone.

Na nitroprusside (fresh dil. sol.) and strong **KOH**: a red colour fading to yellow (NH_4OH: purple); on acidifying with acetic acid the solution becomes purple.

Chloroform. $CHCl_3$.

Colourless liquid with a characteristic pleasant odour and burning taste, very volatile, boils 61·2° C., but not readily combustible; readily sol. in alcohol, ether, and carbon bisulphide; only slightly sol. in water. Dissolves fats, oils and resins.

Use ·5 c.c. for each test.

KOH (strong) and ten times its vol. of **alcohol,** warm: KCl and K formate; to **confirm,** add dil. H_2SO_4 and distil; test the distillate for formic acid.

KOH (in alcohol) and two drops of **aniline**, warm: the nauseous odour of phenyl isocyanide (carbylamine C_6H_5NC).

Fehling's solution, warm: ppt. of Cu_2O.

Phenol and KOH (in alcohol), evaporate to dryness on W.B. and moisten with $CHCl_3$: a purple colour. (Distinction from chloral.)

TESTS FOR IMPURITIES.

Pure chloroform leaves no residue on evaporation in a watch glass.
Gives no ppt. when shaken with $AgNO_3$.
Does not act on litmus paper.
Does not turn $K_2Cr_2O_7$ and H_2SO_4 green in the cold.
Does not oxidize bright sodium.
Does not turn brown with either strong KOH or strong H_2SO_4.

Glycerol or Glycerin. $C_3H_5(OH)_3$.

A colourless, odourless, oil-like liquid, neutral, with sweet taste; boils 290°, and yields acrolein ($C_2H_3.CHO$) recognised by its disagreeable odour. Very hygroscopic, mixes with aq. and alcohol in all proportions; almost insol. in chloroform and in ether.

Marks paper like oil, but the stain is removed on soaking in aq.

Use ·5 c.c. for each test.

Heated alone, or with H_2SO_4, $KHSO_4$, or P_2O_5 : the disagreeable odour of acrolein is evolved.

NaOH, heat : no change.

Borax bead moistened with glycerol and heated in the outer edge of the bunsen flame gives a momentary green colouration.

Sulphur, boil : unpleasant odour of allyl mercaptan, etc.

Phenol, H_2SO_4 and glycerol, each two drops, mix, heat to about 120°; add water and excess of NH_4OH : crimson colour.

UNCLASSIFIED.

Hydroxyl. H_2O_2.

Colourless liquid without odour; generally used as a 10 vol. sol. in water. Decomposed on warming (oxygen evolved) and by organic substances.

TESTS.—Use 1 c.c. for each test.

Litmus sol. : Bleached.

$KMnO_4$ sol. : Bleached.

PbS : Converted into white $PbSO_4$.

KI and starch paste : blue colour from the liberation of iodine.

Ether and $K_2Cr_2O_7$ sol., shake : evanescent blue colour.

Carbon Bisulphide. CS_2.

Colourless, mobile, highly refractive liquid, odour usually offensive, but ethereal when pure. Sp. gr. 1·292. Very volatile, boils 46·6° C., its vapour is extremely inflammable (can be ignited by a test tube containing hot oil); yields SO_2 when burnt; if with insufficient air, in a beaker or tube, S is deposited.

Almost insol. in aq., but readily sol. in alcohol and ether. It readily dissolves S, P, I, caoutchouc, oils and fats.

Use ·5 c.c. for each test.

KOH, boil : brown sol. of K_2CO_3 and K_2CS_3 ; add one drop of Pb acetate : black PbS.

H_2SO_4 (conc.) on shaking : ppt. of S.

KOH (in alcohol) shake : crystals of pot. xanthate.

Urea (Carbamide) $CO(NH_2)_2$.

Crystallizes in four-sided prisms, deliquescent, very sol. in aq. and in alcohol, very slightly in ether. Melts 132° ; taste resembles saltpetre.

DRY TEST.—Heat ·01 gm. in a dry tube : evolves NH_3, etc., the residue contains cyanuric acid and biuret, a sublimate of biuret is also formed ; extract the biuret with warm water, filter, add to filtrate a drop of dil. $CuSO_4$ and excess of NaOH : purple colour.

Heated with **NaOH or Na_2CO_3** : NH_3.

WET TESTS.—Diss ·1 gm. of urea in 7 c.c. aq.

HNO_3 (free from HNO_2) : crystals of urea nitrate (only from strong sols.).

$H_2C_2O_4$ (oxalic acid) : tabular prisms of the oxalate (only from strong sols.).

$Hg2NO_3$: a flocculent ppt. of $CO(NH_2)_2.2HgO$, even in very dil. sols., sol. in NaCl, reprecipitated by further addition of $Hg2NO_3$.

KBrO (or KClO) : decomposes urea with effervescence into CO_2, H_2O and N. (KBrO can be made by adding cold KOH to Br aq. until decolourized.)

HNO_2 (nitrous acid) or a sol. of **KNO_2** and **dil. H_2SO_4** (or $HC_2H_3O_2$) decomposes urea into N and CO_2.

CARBOHYDRATES.

Sugars, Amyloids and Cellulose.

Glucoses. $C_6H_{12}O_6$.

Dextrose (Grape Sugar), $C_6H_{12}O_6, H_2O$. Crystallized, colourless, and without odour ; less sweet than cane sugar.

The crystallized sugar melts at 80° to 86° ; the anhydrous at 146°. Sol. in aq. and in dil. alcohol, insol. in ether.

Dextrorotatory, $[\alpha]_D = + 52{\cdot}5°$; readily ferments with yeast. Its osazone melts at 206°.

Dry tests.—Heated : turns brown and evolves odour of caramel.

H_2SO_4 (conc.) : no change ; warm : dark brown colour. (See sucrose.)

Wet tests.—Diss. 0·1 gm. in 6 c.c. aq.

KOH (strong), warm : brown solution ; on adding HNO_3 changes to yellow and the odour of caramel is evolved. (Compare with cane sugar.)

Pb acetate, boil, add **NH_4OH** until a white ppt. just forms, boil : the ppt. becomes pink colour. (Cane and milk sugars do not give this reaction.)

Cu acetate and two drops of **acetic acid**, warm : ppt. of red Cu_2O. (See milk sugar.)

$AgNO_3$ and NH_4OH, place the test tube in a beaker of boiling water : a silver mirror forms on the test tube.

Fehling's solution : reduced immediately on warming.

KOH and 3 drops of **picric acid** sol., boil : the yellow colour changes slowly to red (picramic acid), $C_6H_2.OH.NH_2.(NO_2)_2$.

Lævulose (Fruit Sugar), $C_6H_{12}O_6$.

Is distinguished from dextrose by its rotating the polarised ray to the left, $[\alpha]_D = -113{\cdot}9°$; by being more sol. in aq. and in alcohol, and by yielding a ppt. with $Ca(OH)_2$.

Saccharoses. $C_{12}H_{22}O_{11}$.

Sucrose (Cane Sugar). Crystallized in colourless oblique prisms ; readily sol. in aq., but sparingly sol. in alcohol. Melts at 160°, when cold is vitreous, *i.e.*, non-crystallized (barley sugar). Dextrorotatory, $[\alpha]_D = + 66{\cdot}5°$. Cane sugar does not form an osazone.

Dry test.—Heated to about 200° it changes to caramel (brown), then chars, evolves gases and a characteristic odour.

H_2SO_4 (conc.), chars sugar and syrup.

WET TESTS.—Diss. 0·1 gm. in 5 c.c. aq.

KOH (strong), heat, does not become brown, nor is the odour of caramel emitted on acidifying with HNO_3. (See glucose.)

Cu acetate alone, or when warmed with **acetic acid,** is not reduced. (See glucoses.)

$AgNO_3$ and NH_4OH, warm : no silver mirror.

Pb acetate and NH_4OH, boil, the white ppt. does not become yellow.

Fehling's solution is not reduced (by a fresh sol. of sugar); if, however, the sugar be previously "inverted" by warming with 2 drops of HCl or H_2SO_4, Fehling's solution is quickly reduced on warming.

LACTOSE (Milk Sugar). $C_{12}H_{22}O_{11},H_2O$.

Crystallizes in prisms, gritty and not so sweet as cane sugar; sol. in aq., insol. in ether and absolute alcohol. Dextrorotatory, $[\alpha]_D = + 52{\cdot}53°$. Its osazone melts at 200°; does not ferment with yeast.

DRY TESTS.—Heated, becomes brown.

H_2SO_4 (conc.), warm : blackens or chars, but less readily than cane sugar.

WET TESTS.—Diss. ·1 gm. in 6 c.c. aq.

KOH, boil : brown colour, discharged on adding dil. HNO_3, and odour of caramel evolved.

Cu acetate (and 2 drops of **acetic acid**) on boiling and standing is not reduced unless the solution be concentrated.

$AgNO_3$ and NH_4OH : Ag mirror when warmed.

Pb acetate, boil and add just sufficient NH_4OH to produce a ppt., again boil, the white ppt. becomes pale yellow; the ppt. from cane sugar remains white and that from glucose becomes pink.

KOH and picric acid, boil : red (picramic acid).

Fehling's solution, warm : red ppt. of Cu_2O.

MALTOSE.—$C_{12}H_{22}O_{11},H_2O$. Crystallized, very sol. in aq., almost insol. in absolute alcohol; readily fermented. Dextrorotatory, $[\alpha]_D = + 140{\cdot}6°$. Its osazone melts 206°.

DRY TEST.—Moisten the powder, add conc. H_2SO_4 : clear sol., chars on warming.

WET TESTS.—Diss. ·1 gm. in 5 c.c. aq.

NaOH, boil : yellow, then brown colour, dil. HNO_3 discharges the colour and the odour of caramel is evolved.

Fehling's solution, boil : red ppt. of Cu_2O.

Cu acetate, and 2 drops of **acetic acid,** is not reduced on boiling.

$Pb2C_2H_3O_2$ and NH_4OH : white ppt., which becomes pink on boiling. (See glucose.)

Picric acid and NaOH : red picramic acid ($C_6H_2,NH_2(NO_2)_2OH$). Glucose and lactose also give this reaction.

General Reaction.

(*a*) When a molecule of a sugar containing an aldehyde (CHO) or a ketone group (CO) is acted upon by phenyl hydrazine it yields a hydrazone.

$$\left\{\begin{matrix} CH_2(OH)(CH.OH)_4CHO \\ \text{Glucose} \end{matrix}\right. + \left\{\begin{matrix} C_6H_5NH.NH_2 \\ \text{Phenyl hydrazine} \end{matrix}\right. =$$

$$H_2O + \left\{\begin{matrix} C_6H_5NH.N{:}HC(CH.OH)_4(OH)CH_2 \\ \text{Glucose phenylhydrazone} \end{matrix}\right.$$

(*b*) When an "excess" of phenylhydrazine is added the CH(OH) group next the end is oxidized to CO, and part of the phenyl hydrazine is reduced to aniline and NH_3, and the oxidation product of the phenyl hydrazone combines with a second molecule of phenyl hydrazine and yields an osazone.

$$CH_2.(OH)(CH.OH)_3CO.CH{:}N.NH.C_6H_5 + \left\{\begin{matrix} C_6H_5NH.NH_2 \\ \text{Phenyl hydrazine} \end{matrix}\right. =$$

$$\left\{\begin{matrix} CH_2(OH)(CH.OH)_3C(N.NHC_6H_5)CH{:}N.NH.C_6H_5 \\ \text{Osazone} \end{matrix}\right. + H_2O$$

Expt.—Diss. ·5 gm. of a sugar in 5 c.c. aq., add 3 c.c. phenyl hydrazine and 3 c.c. acetic acid, place the test tube in boiling water for about ten minutes, when the osazone comes down as yellow crystals.

To identify the sugar, filter off the osazone, wash, dry and determine its melting point or examine its decomposition products.

Summary of Sugar Reactions.

TEST.	GLUCOSE.	SUCROSE.	LACTOSE.	MALTOSE.
Rotation	$[\alpha]_D = +52·5°$.	$[\alpha]_D = +66·5°$.	$[\alpha]_D = +52·53°$.	$[\alpha]_D = +140·6°$.
Heated alone	Browns and yields caramel.	Yields barley sugar and caramel.	Browns.	
H_2SO_4 (conc.)	No change, chars on warming.	Chars in the cold.	Chars on heating.	Chars on heating.
NaOH sol., heated	Becomes brown; add HNO_3 = caramel odour.	No change.	Becomes brown; add HNO_3 = caramel odour.	Becomes brown; add HNO_3 = caramel odour.
Pb. acetate and NH_4OH	Pink ppt.	White ppt.	Yellow ppt.	Pink coloured ppt.
Cu acetate and acetic acid	Cu_2O on boiling.	No change.	No change.	No change.
Fehling's sol.	Cu_2O on boiling.	No change.	Cu_2O on boiling.	Cu_2O on boiling
Phenyl hydrazine	Yellow crystals of glucosazone, m.p. 206°.	No osazone.	Yellow crystals, Lactosazone. m.p. 200°.	Yellow crystals of Maltosazone m.p. 206°.

Amyloids. $(C_6H_{10}O_5)_n$.

STARCH.—White powder, with peculiar harsh feel when rubbed between the fingers. Under the microscope the grains of many varieties of starch are seen to be made up of concentric layers, and to show a well-marked cross with Nicol's prisms. Insol. in cold aq.; in hot aq. the granules burst and yield a translucent fluid, strong sols. set to a jelly: "starch paste."

DRY TESTS.—When heated (to 150° C.) it is changed into dextrin (or British gum) which is sol. in aq., and gives a reddish colour with tincture of iodine, instead of blue. At higher temps. it chars and emits an unpleasant odour.

WET TESTS.—Grind ·01 gm. starch with 1 c.c. of cold aq., make up to 5 c.c. with aq. and boil.

Iodine (tincture): a blue colour, which disappears on boiling, but returns when cold, if not boiled too long.

Reducing substances, *e.g.*, Na_2SO_3, $Na_2S_2O_3$, and SH_2 prevent the formation of the blue colour; if such are present, add 3 drops of $K_2Cr_2O_7$ and 5 of HCl.

H_2SO_4 (conc.), warm: blackens, CO_2 and SO_2 evolved.

H_2SO_4 (dil.), warm for some time: a mixture of dextrose and dextrin, add iodine: red colour.

Alcohol (excess): white ppt.

Basic Pb acetate, $Ba(OH)_2$, $Ca(OH)_2$, tannin, etc., also ppt. starch.

Br aq. to a sol. of starch in HCl: yellow colour.

Fehling's solution: ppt. of Cu_2O. (Test for dextrose by boiling with Cu acetate and acetic acid: Cu_2O ppt.)

Diastase and certain other enzymes convert it into a mixture of dextrin and maltose.

INULIN, a variety of starch from chicory, artichokes, dahlia tubers, etc., is coloured yellow by iodine.

DEXTRIN (British Gum). $(C_6H_{10}O_5)_n$.

Amorphous powder, readily softens and is sol. in cold aq.; gum-like taste; insol. in strong alcohol.

WET TESTS.—Boil ·1 gm. in 5 c.c. aq.

Iodine (tincture): reddish colour; the commercial article gives a blue colour with I.

HCl, H_2SO_4, and HNO_3 (dil.) on boiling convert it into dextrose.

Cu acetate: slowly reduced on warming.

Fehling's solution slowly reduced on boiling.

Tribasic lead acetate, no ppt., add NH_4OH: ppt.

GUM ARABIC. The chief constituent is the Ca salt of arabic acid, $(C_6H_{10}O_5)$.

Occurs in yellow or colourless translucent drop or tears, softens in cold water; composed of arabic acid and mineral matter.

Heated : fuses, gives off odour of caramel, and leaves a white ash.

WET TESTS.—Diss. ·1 gm. in 5 c.c. aq.

Iodine (tincture) : no colour, hence distinguished from starch, dextrin, etc.

$Ca(OH)_2$, KOH and NaOH each give white ppts. of gum arabic, but if mineral acids (*e.g.*, HCl) be present, **arabic acid** is pptd.

Alcohol : white ppt.

$CuSO_4$ sol. and excess of NaOH : a bluish ppt., not reduced or blackened on boiling, as is the case with dextrin and the sugars.

Basic Pb acetate : a white gelatinous ppt. This also distinguishes it from dextrin and sugar.

CELLULOSE. $(C_6H_{10}O_5)_n$.

Use ·01 gm. of cotton wool for each test.

H_2SO_4 (conc.) : solution, reprecipitated on dilution.

$Cu(OH)_2$ in strong NH_3 : solution ; reprecipitated on dilution and by acids.

$ZnCl_2$: solution, which does not become blue with iodine.

H_2SO_4 (dil.), boil : converted into dextrose and dextrin.

KOH, $Ba(OH)_2$, etc. : form salts.

HNO_3 (conc.) converts it into guncotton.

GLUCOSIDES.

Glucosides are vegetable compounds, which when acted upon by acids or alkalis generally yield glucose and one or more other substances.

SALICIN. ($C_{13}H_{18}O_7$). Crystallizes in silky needles ; bitter taste ; melts 196°. Sol. in alcohol, KOH, NaOH, glacial acetic acid, in 30 parts of cold and in 1 of hot water, but insol. in ether.

DRY TEST.—Heated in a dry tube it melts, chars and emits the odour of caramel.

COLOUR TESTS.—Use ·001 gm. for each test.

H_2SO_4 (conc)., on watch-glass or porcelain : red colour.

Mandelin's reagent (see index) : purple colour.

Froehde's reagent (see index) : violet colour.

Erdmann's reagent (see index) : red, with purple edges.

WET TESTS.—

H_2SO_4 (dil.), warm : glucose, $C_6H_{12}O_6$, and saligenin $C_6H_4CH_2(OH)_2$, now warm with 2 c.c. Fehling's sol. : ppt. of Cu_2O.

$K_2Cr_2O_7$ (powder) and (conc.) **H_2SO_4** added to the above hydrolysed solution on warming : salicylal, recognised by its odour of oil of meadow sweet.

$AgNO_3$, NH_4OH, and 2 drops of **KOH,** warm : mirror of reduced silver.

DIGITALIN. ($C_{29}H_{46}O_{12}$). White powder ; melts 217°. Readily sol. in aq. and hot absolute alcohol, sparingly sol. in cold alcohol, ether and chloroform. Does not evolve nitrogenous odour when heated.

COLOUR TESTS.—Use ·001 gm. for each test.

H_2SO_4 (conc.) : yellow, brown, and finally red.

H_2SO_4 (conc.) and **$K_2Cr_2O_7$** (powdered) : brown, changing to green.

H_2SO_4 (conc.), stir with rod dipped in **Br aq.** : red-brown colour.

Erdmann's and Froehde's reagents : brown colour.

Mandelin's reagent : red-brown, changing to cherry-red.

WET TESTS.—

$AgNO_3$, NH_4OH, and a drop of **KOH,** warm : silver mirror.

AROMATIC COMPOUNDS.

Benzene. C_6H_6.

Mobile colourless liquid, with characteristic (coal gas-like) odour. Boils 80° C.; sp. gr., ·88; very volatile; burns readily with a luminous smoky flame; almost insol. in H_2O, readily sol. in alcohol and ether.

WET TESTS.—Use 5 drops for each test.

H_2SO_4 (conc.): no change.

HNO_3 (conc.), mixed with conc. **H_2SO_4**; when the action ceases pour into a beaker of aq.: nitro-benzene ($C_6H_5.NO_2$) separates out as yellow oily drops. Note the odour of bitter almonds.

NOTE.—**Benzine or benzoline** is a mixture of the light paraffin oils (C_nH_{2n+2}), with a sp. gr. of about ·72. It usually contains some C_6H_6.

It is unacted upon by either H_2SO_4 or HNO_3 (cold).

Phenol (Carbolic Acid). $C_6H_5.OH$.

Colourless crystals; becomes pink or brown on exposure to air. Strong characteristic odour; sparingly sol. in cold aq., readily in hot aq., in spirit, ether, H_2SO_4, KOH and NaOH. Melts 41° C.; boils 181·5° C.

WET TESTS.—Diss. ·1 gm. in 8 c.c. aq.

$FeCl_3$: violet colour, destroyed by both acids and alkalis.

NH_4OH and 5 drops of **bleaching powder** sol. or **Br aq.**, warm: a fine blue colour.

Pine wood soaked in **HCl** and moistened with phenol becomes pink or purple, exposure to light deepens the colour. (See aniline.)

Collodion: a jelly.

HNO_3 (conc.), warm: bright yellow solution of picric acid.

Albumen is coagulated.

Br aq.: a yellow ppt. of tribromo-phenol, $C_6H_2Br_3.OH$.

Liebermann's reagent (6 gm. KNO_2 in 100 gm. of H_2SO_4, or a fragment of KNO_2 the size of a pin's head, dissolved in ½ c.c. (conc.) H_2SO_4), gives a blue colour with strong sols.; when poured into aq. it changes to red; alkalis restore the blue colour.

VOLATILE BASES.

Aniline (Phenylamine). $C_6H_5NH_2$.

Colourless oily liquid, becomes brown on exposure to the air, faint odour; neutral to litmus. Boils 183·7°; burns with smoky flame. Slightly sol. in cold aq., readily sol. in alcohol, ether and chloroform.

Yields crystallized salts with acids. KOH and NaOH (but not NH_4OH) decompose the salts and set free the aniline.

WET TESTS.—Use 1 drop of aniline from the end of a glass rod for each test.

H_2SO_4 (conc.) : solution, on long boiling becomes brown; stir a dil. sol. of $K_2Cr_2O_7$ (in test tube, watch-glass or porcelain basin) with a glass rod dipped into the above solution : blue colour.

The following tests apply to both the base and its salts.

NaOH in alcohol and 2 drops of **chloroform,** warm : nauseous odour of carbylamine (phenol isocyanide).

NaOCl, or bleaching powder solution : purple colour. Then add dil. NH_4SH : magenta colour, fleeting.

$KClO_3$ (dil.) to dil. aniline sol., 1 drop to 5 c.c. aq., then run a little conc. H_2SO_4 carefully down the side of the tube : a violet colour ring at the junction of the liquids.

Bromine water : pinkish ppt. of tri-bromaniline ($C_6H_2.Br_3NH_2$).

Diazo reaction. Add 5 drops of KNO_2 to a sol. of aniline in dil. HCl cool the test tube under the tap, next add a few drops of α or β naphthol in NaOH : the scarlet colour of benz-azo-naphthol ($C_6H_5N{:}N.C_{10}H_6OH$).

Pyridine. C_5H_5N.

Colourless oily liquid, with strong characteristic odour. Obtained from bone oil and the distillation of alkaloids. Fumes with volatile acids; darkens on exposure. Boils 116°; sol. in aq., alcohol and ether. A strong base, precipitates $Fe(OH)_3$, $Al(OH)_3$ etc., from their salts. Yields salts with acids, from which NaOH and KOH set free the pyridine.

WET TESTS.—Use 1 drop of pyridine for each test.

H_2SO_4 (conc.) : white ppt., dissolves in excess to a colourless sol.

Br aq. in excess added to the **HCl sol.** of pyridine : yellow ppt. ($C_5H_5NBr_2$).

H_2PtCl_6 and HCl, boil and cool : orange-yellow ppt. of $(C_5H_5N)_2.H_2PtCl_6$.

Quinoline. C_9H_7N.

Colourless, limpid liquid, obtained from bone oil and coal tar; with peculiar, somewhat aromatic odour, becomes brown on exposure. Boils 238°. Its vapour burns with a luminous, smoky flame. Sparingly sol. in aq., but readily in many organic liquids. A strong base, yields deliquescent salts. It precipitates $Fe(OH)_3$, $Al(OH)_3$, etc., from their salts.

WET TESTS.—Use 1 drop for each test.

H_2SO_4 (conc.) : crystals of sulphate, soluble in excess.

H_2PtCl_6 to the HCl sol. : yellow ppt. of $(C_9H_7N)_2H_2PtCl_6$; sol. in warm aq.

$AgNO_3$ on shaking : white ppt. which dissolves on warming, but re-forms on cooling; on long boiling some silver is reduced.

$K_2Cr_2O_7$ and 3 drops of HCl : ppt. of yellow crystals of dichromate, $(C_9H_7N)_2H_2Cr_2O_7$, dissolves on warming. (Distinction from pyridine.)

ALKALOIDS.

General Precipitants.

The alkalis and alkali carbonates precipitate many of the alkaloids from strong sols. of their salts.

Platinum Chloride (Chloroplatinic acid), H_2PtCl_6, forms with the hydrochlorides of the alkaloids, salts similar to $(NH_4)_2PtCl_6$ in which the NH_4 is replaced by the alkaloid; these salts, when soluble, are most readily formed by evaporating H_2PtCl_6 with the hydrochloride of the alkaloid over a water-bath; extract the residue with alcohol.

Solution of Iodine in KI (deci-normal sol.) precipitates the alkaloids as yellow or brown polyiodides; to convert these into sulphates evaporate the well-washed ppt. to dryness with H_2SO_4 over a W.B.

Sols. of HgI_2 in KI, of CdI_2 in KI, and of BiI_3 in KI also yield ppts. with the alkaloids.

Tannic acid : white, yellowish or brownish ppts.; the alkaloid can be obtained from these in the free state by adding KOH and taking up with ether, amyl alcohol, benzene, etc.

Phospho-molybdic acid. Gives yellow ppts. with alkaloids. To prepare it boil Am. molybdate with Na_2HPO_4, well wash the ppt., diss. in warm Na_2CO_3, evaporate to dryness, ignite; if reduction takes place (add HNO_3 and re-ignite) warm with water and dissolve in a large excess of HNO_3.

Picric acid. Gives yellow ppts. with most alkaloids.

DIRECTIONS FOR APPLYING THE TESTS.

Colour tests.—Perform the colour tests on a glass plate over white paper, or on a white porcelain slab; those requiring heat should be done on watch-glasses, porcelain crucible lids, or clean pieces of broken dishes. Use 1 drop of the reagent and a small quantity of the alkaloid, about ·2 mgm., or a quantity not larger than the size of a pin's head, for each test, unless otherwise directed; for liquids use 1 drop from the end of a thin glass rod about ⅛ inch thick. Bring the reagent and substance into contact with a pointed glass rod.

VOLATILE LIQUID ALKALOIDS.

Coniine. $C_8H_{17}N$. (Propyl Piperidine).

Colourless oily liquid, becomes brown on exposure, with offensive mouse-like odour, sol. in water, alcohol, etc.; distils in steam; a strong base.

Dissolve 1 drop in 5 drops of water.

COLOUR TESTS.—H_2SO_4 : colourless sol., blackens on heating.

H_2SO_4 and $K_2Cr_2O_7$: green colour.

WET TEST.—**Alcohol**, add 2 drops to 1 drop of a solution of coniine, in an evaporating dish, then 2 drops CS_2, let stand 3 minutes, add one drop of dil. $CuSO_4$: a brown colour. (Distinction from nicotine.)

Nicotine. $C_{10}H_{14}N_2$.

Colourless volatile liquid, with strong characteristic odour, turns brown on exposure. Boils at 250° with decomposition, readily distilled in steam. Readily sol. in aq,, alcohol and ether.

TESTS.—The odour is one of the best tests.

Formaldehyde, mix 2 drops of formalin with 2 drops of a 10 per cent. sol. of nicotine on porcelain, then add 2 drops of HNO_3 : pink colour. (Distinction from Coniine.)

NON-VOLATILE SOLID ALKALOIDS.

(Arranged in alphabetical order.)

Atropine and Daturine (Isomers). $C_{17}H_{23}NO_3$.

COLOUR TESTS.—Divide 1 mgm. into 3 parts.

H_2SO_4 : colourless sol., brown on warming. A pleasant odour of flowers when heated with H_2SO_4 or H_2CrO_4.

HNO_3 (fuming) : solution, evaporate to dryness over W.B., and add 1 drop of alcoholic KOH to the colourless residue : violet, and then cherry-red colour.

Ba water, evaporate and heat strongly : odour of hawthorn blossom.

Brucine. $C_{23}H_{26}N_2O_4.4H_2O$.

Colourless, right rhombic prisms or needles. Sparingly sol. in cold aq., readily sol. in alcohol, amyl alcohol, chloroform, but less in benzene; nearly insol. in ether. Its salts are readily sol. in water.

Brucine and its salts are very bitter and poisonous.

When carefully heated it loses water and sublimes unchanged.

COLOUR TESTS.—Divide 1 mgm. of brucine nitrate into 7 parts.

H_2SO_4 (conc.) : a pale rose tint becoming yellow, and a fleeting red if a trace of HNO_3 be added (characteristic).

H_2SO_4 and solid $K_2Cr_2O_7$: red-brown colour.

HNO_3 (conc.) : a deep red colour, yellow on warming; drive off the free HNO_3 over a water bath and add a drop of $SnCl_2$: a deep purple colour.

Cl water : a fleeting pink or red colour, turning to a yellowish brown on addition of NH_4OH.

Erdmann's reagent (see index) : pale red changing to yellow or orange.

Mandelin's reagent (see index) : rose colour, rapidly changing to orange.

$Hg(NO_3)_2$ (free from acid) : colourless sol., warmed on a water bath : carmine. (Distinction from strychnine.)

PRECIPITANTS.—Diss. 1 mgm. of brucine nitrate in 3 c.c. of aq. **The alkalis and their carbonates** precipitate brucine from its salts.

NH_4OH : ppt. sol. in excess, but it slowly crystallizes out on standing.

KCNS : white ppt. sol. in excess.

Caffeine (Theine). $C_8H_{10}N_4O_2$.

Silky needles, bitter taste; sol. in alcohol and ether. Melts 232°. Sublimes unchanged; a weak base.

DRY TEST.—**Soda lime,** heat : NH_3 evolved; carbonate and cyanide left; test for cyanide by HCl and Fe salts.

COLOUR TESTS.—Divide 1 mgm. into 4 parts.

H_2SO_4 (conc.), and dry **$K_2Cr_2O_7$** : a green colour slowly appears.

HNO_3, evaporate to dryness : a yellow-red stain; cool and add NH_4OH : purple (murexide).

Br water, dry on W.B. : yellow to crimson residue, add NH_4OH : purple (murexide).

Mayer's reagent (see index), no change. (Distinction from other alkaloids.)

WET TEST.—**NaOH,** boil : fish-like odour of methylamine.

Cinchonine. $C_{19}H_{22}NO_2$.

Crystallizes in lustrous prisms. Sparingly sol. in aq., more sol. in alcohol, amyl alcohol, ether and chloroform. Bitter taste. Melts 255° to a colourless fluid.

DRY TEST.—If cautiously heated in a dry tube it sublimes unchanged.

COLOUR TESTS.—Divide 1 mgm. into 3 parts.

H_2SO_4 (conc.) : colourless sol.; warm : brown to black.

HCl, and evaporate to dryness : purple colour and purple vapours, the same as quinine and quinidine.

Mandelin's reagent : same as quinine and quinidine.

PRECIPITANTS.—Diss. 1 mgm. cinchonine sulphate in 3 c.c. aq. This sol. is not fluorescent.

NaOH, KOH, NH_4OH and their carbonates : precipitates of amorphous cinchonine from its salts.

Cl water, 5 drops, and 5 drops NH_4OH : yellowish ppt.

K_4FeCy_6 : flocculent ppt. of cinchonine ferrocyanide, sol. in excess of K_4FeCy_6 on warming, on cooling it crystallizes out in brilliant yellow scales or needles.

Cocaine (Methyl-benzoyl-ecgonine). $C_{17}H_{21}NO_4$.

Colourless prisms. Melts 98°; sublimes at higher temps. Readily sol. in alcohol, ether, chloroform, benzene, and petroleum; sparingly in water. Its salts are readily sol. in water.

COLOUR TESTS.—Divide 1 mgm. of cocaine hydrochloride into 3 parts.

H_2SO_4 : no colour, add a particle of $K_2Cr_2O_7$: brown colour.

$KMnO_4$ (strong sol.), add to alcohol sol. in watch-glass : purple ppt. of cocaine permanganate.

$K_2Cr_2O_7$ and 2 drops **HCl,** on watch-glass : light yellow ppt. (characteristic).

WET TESTS.—Diss. 1 mgm. cocaine hydrochloride in 2 c.c. aq.

H_2SO_4 (conc.), warm : odour of benzoic acid ; add 2 c.c. alcohol, boil : odour of ethyl benzoate.

$FeCl_3$, one drop, boil : red-brown colour.

Codeine (Methyl morphine). $C_{17}H_{17}NO(OCH_3)OH$.

Crystallizes in orthorhombic prisms. Melts at 150°. Moderately sol. in hot aq.; readily sol. in alcohol, amyl alcohol, ether, chloroform and benzene. Alkaline reaction.

COLOUR TESTS.—Divide 1 mgm. into 5 parts.

H_2SO_4 : colourless sol. ; blue when warmed ; (*a*) add $FeCl_3$ to cold sol. : deep blue ; (*b*) grind with sugar : purple-red on standing.

HNO_3 : a yellow colour.

Froehde's reagent : green and finally blue sol.

Cl water : dissolves ; add **NH_4OH** : orange.

Moisten with **formalin,** add 2 drops conc. H_2SO_4 : violet colour.

Morphine. $C_{17}H_{19}NO_3,H_2O$.

Crystallizes in colourless prisms, sol. in alcohol and amyl alcohol, almost insol. in cold aq., ether, chloroform and benzene ; sparingly sol. in hot aq., poisonous.

COLOUR TESTS.—Divide 1 mgm. of morphine hydrochloride into 8 parts.

H_2SO_4 : pale rose colour ; warm : violet and then brown, add a trace of HNO_3 and warm : red colour.

H_2SO_4 and a particle of **$K_2Cr_2O_7$** : dull green colour.

H_2SO_4 (conc.) 2 drops, and a fragment of $FeSO_4$, warm on a W.B. for one minute, stir, cool, add excess of NH_4OH : pink, then red and violet. (Distinction from codeine.)

Formalin, 1 drop, and 2 drops conc. H_2SO_4 : deep purple colour.

HNO_3 : bright orange colour.

$FeCl_3$ (neutral) : an indigo blue colour with strong sols. of morphine salts.

Froehde's reagent : violet, changing to green.

Iodic acid, one drop : free iodine.

PRECIPITANTS.—Diss. 1 mgm. of morphine hydrochloride in 2 c.c. aq.

NaOH, KOH, NH_4OH and their carbonates : ppt. of morphine, readily sol. in an excess.

Narcotine. $C_{22}H_{23}NO_7$.

Colourless lustrous prisms or needles. A weak base.

COLOUR TESTS.—Divide 1 mgm. into 4 parts.

H_2SO_4 (conc.) : yellow solution changing to red and dusky violet when warmed slowly on a water bath. $FeCl_3$ restores the red colour.

H_2SO_4 (conc). and dry **$K_2Cr_2O_7$** : rich brown colour.

HNO_3 : yellow solution, orange on warming.

Froehde's solution : green sol. ; warm : red.

PRECIPITANTS.—Diss. 1 mgm. narcotine in 2 c.c. dil. HCl.

Cl water : greenish yellow ; add NH_4OH : orange (only from strong sols.).

Br water added drop by drop to the HCl sol. : yellow ppt. ; boiled : red colour. Destroyed by slight excess of Br.

Papaverine. $C_{20}H_{21}NO_4$.

Crystallized in prisms, feebly alkaline, not poisonous, soluble in hot alcohol, crystallizes on cooling ; insol. in water.

COLOUR TESTS.—Divide 1 mgm. into 3 parts.

H_2SO_4 : colourless or yellow solution becoming violet on warming.

Froehde's reagent : green through blue to violet colour, and cherry red.

Cl water and NH_4OH : red-brown colour, turning to very dark brown.

Iodine solution (with strong sol.) : dark red, then brick-red and dark red again.

Quinine. $C_{20}H_{24}N_2O_2,3H_2O$.

Crystallized ; slightly sol. in cold aq., more soluble in hot water and NH_4OH, in alcohol, chloroform, ether, petroleum, and benzene. Bitter taste ; turns litmus blue. Solutions of quinine salts, especially of the sulphate and other oxidized acids, exhibit a strongly marked blue fluorescence.

COLOUR TESTS.—Divide 1 mgm of quinine sulphate into 3 parts.

H_2SO_4 (conc.) : colourless solution, add particle of $K_2Cr_2O_7$: grass green.

HCl (conc.) evaporate to dryness in porcelain dish : a violet colour just before it chars, and violet vapours, like iodine, are evolved.

Mandelin's reagent : no change : add one drop HNO_3 : violet.

PRECIPITANTS.—Diss. 1 mgm. quinine sulphate in 2 c.c. aq.

Ammonia, alkalis, and their carbonates : ppt. of amorphous quinine from strong sols., which gradually becomes crystalline.

Cl water and an excess of **NH_4OH** : a green colour. Add 3 drops of esh K_3FeCy_6 sol. to this : bright red.

Strychnine. $C_{21}H_{22}N_2O_2$.

Strychnine and all its salts are **virulent** poisons. Crystallizes in white rhombic prisms. Readily soluble in hot chloroform; very sparingly sol. in hot water (1 in 2500), benzene, amyl alcohol, absolute alcohol and ether; slightly sol. in dil. alcohol. Its **salts** are sol. in aq. and in alcohol, but insol. in ether, chloroform, amyl alcohol and benzene; all have a bitter taste, 1 part in 700,000 of aq. can thus be recognised.

COLOUR TESTS.—Divide 1 mgm. of strychnine sulphate into 3 equal parts.

H_2SO_4 (conc.), and a fragment of either **$K_2Cr_2O_7$, MnO_2, PbO_2, or K_3FeCy_6** : beautiful purple colour changing to red and green.

NOTE.—This test does not answer with St. nitrate, nor with the sulphate in the presence of antipyrine. Strychnine is often added to antipyrine for medicinal purposes.

HNO_3 (conc.) : colourless sol., yellow when warmed.

Mandelin's reagent : blue colour changing to violet; NH_4OH changes it to rose colour. Characteristic.

PRECIPITANTS.—Diss. 1 mgm. of strychnine sulphate in 4 c.c. aq.

KOH and NaOH and their carbonates give with St. salts, white crystalline ppts. The ppt. with NH_4OH is sol. in an excess, but gradually crystallizes out in needles.

Cl water : white ppt., sol. in excess.

Iodine (strong sol. in KI) : reddish brown ppt.

KCNS : a white ppt. insol. in excess; slowly formed in dil. sols.

Veratrine. $C_{37}H_{53}NO_{11}$.

Amorphous, white or grey, crystallizes from alcohol, No odour, but causes violent sneezing. Sol. in $CHCl_3$ and alcohol, sparingly in ether and amyl alcohol.

COLOUR TESTS.—Divide 1 mgm. into 7 equal parts.

H_2SO_4 : yellow solution, red when heated.

HNO_3 : pale yellow to green.

HCl (conc.) : colourless sol.; boil : red colour.

Erdmann's reagent : yellow to deep red.

Mandelin's reagent : dusky yellow to crimson.

Froehde's reagent : yellow, becoming cherry-red on standing.

When rubbed with 3 times as much cane sugar and H_2SO_4 (2 drops) it becomes yellow (green by reflected light) and finally indigo blue.

ARTIFICIAL ALKALOIDS.

Acetanilide (Antifebrin). $C_6H_5.NH.COCH_3$.

Crystallizes in colourless lustrous plates. Melts 113°. Readily soluble in alcohol, ether, chloroform and boiling aq.

COLOUR TESTS.—

H_2SO_4 (conc.), stir with a little powdered $K_2Cr_2O_7$: red streaks, quickly turning green.

Mandelin's reagent : orange red ; this becomes red and then grey.

Hg_2NO_3, 2 drops, on slow evaporation : green residue; stir this with a little conc. H_2SO_4 : deep red.

WET TESTS.—Diss ·1 mgm. in 3 c.c. of alcohol.

$FeCl_3$, boil, becomes turbid and darker in colour. (See antipyrine and phenacetin.)

KOH, warm : K acetate and aniline. Test for the aniline by warming with 2 drops of $CHCl_3$: odour of carbylamine ; or dilute with aq., shake up with ether, separate the ethereal sol. and test it for aniline ; test the water sol. for acetic acid.

H_2SO_4 (conc). and alcohol, warm : odour of ethyl acetate.

Antipyrine (Phenazone). $C_{11}H_{13}N_2O$.

Colourless, odourless crystals. Melts 114°. Bitter taste, neutral reaction, yields salts. Soluble in water and in alcohol, sparingly in ether.

DRY TEST.—Heated in a dry tube : melts and chars, a brown liquid condenses.

COLOUR TESTS.—Divide 1 mgm. into 6 parts.

H_2SO_4 (conc.), warm : colourless.

HNO_3 (conc.), warm : yellow to red colour.

$HgCl_2$: white ppt., dissolves on warming ; re-formed on cooling.

KNO_2, fragment, and 2 drops dil. H_2SO_4 : bright reddish-yellow colour (isonitroso-antipyrine). Strong sols. of antipyrine yield green crystals.

Mandelin's reagent : pale blue colour, evanescent.

$FeCl_3$, warm : deep red colour.

Phenacetin (para-acetamido-ethoxybenzene). $C_2H_5O.C_6H_4.NH.COCH_3$.

Colourless, odourless, crystalline scales. Melts 135°. Almost insol. in cold aq., fairly sol. in hot water and readily sol. in ether and chloroform.

DRY TESTS.—**Heat** in a dry tube : melts and sublimes.

Mix with twice its bulk of **zinc dust** or filings, and heat to charring; cool, boil with a little water, filter, add $FeCl_3$: violet colour, due to the salicylic acid formed.

COLOUR TESTS.—Use 1 mgm. divided into 2 parts.

HNO_3 (1 to 1 aq.) warm : orange colour, and yellow crystals on cooling. Add KOH in excess : red colour, which deepens on boiling.

KNO_2, grind with an equal bulk of phenacetin, mix with 2 drops conc. H_2SO_4 and warm on a water-bath : green colour.

WET TESTS.—Diss. 1 mgm. in 2 c.c. aq.

$FeCl_3$ (dil. sol.) warm : red colour.

H_2SO_4 (conc.) and alcohol, warm : odour of ethyl acetate.

DETECTION OF SINGLE ALKALOIDS.

1. Heated on Pt foil : nitrogenous odour and smoky flame.

2. Heated with soda-lime : odour of NH_3.

3. Placed on litmus paper and moistened with alcohol, a blue colour : a free alkaloid.

The solution of the salt of the alkaloid must not be too dilute, and must be free from substances which would interfere with the tests.

GROUP I.—ATROPINE, (ANILINE), CONIINE, NICOTINE AND MORPHINE.

Add KOH to the sol. until it is just alkaline ; stir briskly and allow to stand.

a. **No ppt.** ; (1). Heat with H_2SO_4 or H_2CrO_4 ; a characteristic pleasant odour of flowers. (2) Iodine is not separated on addition of HIO_3 : **atropine.**

b. **A disagreeable odour** is evolved and oily drops separate : **(aniline), nicotine, coniine.**

Extract with ether and evaporate the ethereal extract to dryness with HCl :—

An amorphous residue : nicotine hydrochloride.

A crystalline residue ; when boiled with HNO_3 becomes red, violet, green, blue, and finally brown, especially if free acid be present : **coniine.**

c. **A ppt. sol. in excess : morphine or atropine.**

Confirm.—Add **iodic acid,**

Iodine is not separated : **atropine.**

Iodine separates out : **morphine.**

$FeCl_3$ neutral (dil.) : a blue or green colour, if the sol. be concentrated and neutral : **morphine.**

GROUP II.—CINCHONINE, NARCOTINE AND QUININE.

Add 2 drops dil. H_2SO_4 and just neutralise with a saturated solution of $NaHCO_3$, stir well and allow to stand 30 minutes.

A precipitate : cinchonine, narcotine or quinine.

Heat cautiously : fuses and yields a sublimate of white needles : **cinchonine.**

NH_4OH in excess, and shake with ether, (*a*) the ppt. does not dissolve : **cinchonine** ; (*b*) it dissolves : **narcotine or quinine.**

K_4FeCy_6 to a neutral sol. : a white ppt. sol. in excess; warm, bright yellow crystals separate out on cooling : **cinchonine.**

Cl water and 2 drops of **NH_4OH,** (*a*) a deep red solution : **narcotine** ; (*b*) a green or blue sol. : **quinine.**

GROUP III.—BRUCINE, CAFFEINE, COCAINE, CODEINE, DIGITALIN, PAPAVERINE, PICROTOXIN, QUININE, SALICIN, STRYCHNINE, VERATRINE.

If the substance be liquid, evaporate to dryness on a watch-glass and stir the residue with a glass rod dipped in conc. H_2SO_4.

a. **A rose colour** becoming intensely red on addition of HNO_3 : **brucine.** **Confirm** (1) Cl water (the gas is better) : red. NH_4OH changes this to yellowish brown ; (2) HNO_3 gives blood red, then yellow, changed to violet on addition of $SnCl_2$.

b. **A yellowish colour,** becoming orange red and finally crimson on heating : **veratrine. Confirm.** Mix with 3 times its bulk of cane sugar and moisten with strong H_2SO_4 : reddish brown, gradually turning to blue.

c. **Colourless or faint yellow on standing** : caffeine, cocaine, codeine, papaverine, quinine and strychnine.

Confirm for caffeine.—HNO_3, dry on W.B., add NH_4OH : purple colour (murexide). **Confirm** for cocaine.—$K_2Cr_2O_7$ and 2 drops of HCl : light yellow ppt. **Confirm** for codeine.—H_2SO_4 and $FeCl_3$: deep blue colour. **Confirm** for papaverine.—Iodine solution : dark red. **Confirm** for quinine.—(1). Fluorescence in solutions of its salts; (2) Cl water and then NH_4OH : green. **Confirm** for strychnine.—(1) KCNS : white crystalline ppt. ; (2) a bitter taste in very dil. solutions; (3) conc. H_2SO_4 and solid $K_2Cr_2O_7$: deep blue colour changing to wine red.

d. **A reddish-brown colour.**

Br water, the reddish-brown colour changes to purple : **digitalin. Confirm.**—Warm the solution in water with phospho-molybdic acid : bright green, which changes to blue on adding NH_4OH : **digitalin.**

e. **A saffron colour,** add $K_2Cr_2O_7$ (powder) a violet or brown colour changing to blue : **picrotoxin. Confirm.**—(1) Moisten the substance with HNO_3, dry on water bath and stir with a rod dipped in H_2SO_4, then mix with excess of KOH : orange colour ; (2) add Fehling's solution, warm, ppt. of Cu_2O : **picrotoxin.**

f. **A blood-red colour** : **salicin. Confirm.**—(1) $FeCl_3$: a pale brown, colourless on boiling and a dull yellow ppt. ; (2) $AgNO_3$, warm, add excess of NH_4OH and NaOH, a mirror of reduced Ag : **salicin.**

NOTE.—Digitalin, Picrotoxin and Salicin are not alkaloids, but resemble them physiologically.

TABLES

FOR

QUALITATIVE CHEMICAL ANALYSIS.

PRELIMINARY EXAMINATION.

LIQUIDS.—If the substance be a **liquid**, examine its reaction with litmus paper :—

It is neutral.—Free acids, acid salts and the majority of the normal salts of the heavy metals must be absent.

It is acid.—Either free acids, acid salts or normal salts having an acid reaction, may be present.

It is alkaline.—Salts possessing an alkaline reaction, free alkalis, alkaline earths or their borates, carbonates, cyanides, silicates, phosphates or sulphides may be present.

Evaporate a portion of the liquid in a watch-glass or on a piece of platinum foil. If it does not leave a residue the liquid may be water only; if a residue be left, evaporate a larger quantity in a porcelain dish. The residue should be examined and described as to colour, crystalline form, etc., and then submitted to the preliminary tests as laid down for solids.

SOLIDS.—Examine the substance carefully for traces of crystalline form or structure, note down the colour, lustre, degree of transparency, hardness, density, *i.e.*, whether it has a light or heavy feel; the odour, if any; also the feel when rubbed between the fingers; and ascertain whether it is attracted by a magnet.

PRELIMINARY TESTS.

The substance must first be ground down to the finest powder possible, unless it be already in that state.

When several substances are present together in a mixture, the results obtained may not be exactly as they are here stated, since one reaction often masks or obscures another.

Experiment I.—**Heat some of the powder in an ignition tube,** *i.e.*, in a piece of hard glass tubing about 2 inches long by ¼ inch wide, and closed at one end.

Results.		*Inferences.*
1. The substance does not change.		Absence of organic matter, moisture, combined water and salts of NH_4, Hg, As, etc.
2. It decrepitates.		Presence of nitrates, chlorates, sodium chloride, etc.
3. It changes colour without fusing.		
Cold.	*Hot.*	
White.	Yellow.	ZnO.
White or yellow.	Yellowish brown.	SnO_2, TiO_2.
Red-brown.	Dark red.	Fe_2O_3.
Red.	Black ; Hg globules	HgO.
4. It changes colour and fuses.		
Yellow.	Yellow or red-brown	PbO.
White or yellow.	Orange or brown.	Bi_2O_3.
Yellow.	Dark red.	K_2CrO_4.
Red.	Black.	Pb_3O_4.
5. The substance chars and evolves empyreumatic odours and decomposition products.		Presence of organic matter.
Chars readily, smell of burnt feathers.		Urates, alkaloids and proteids.
A smell of burnt sugar (caramel) is given off, afterwards becoming pungent.		From sugar, tartrates, citrates, malates, tannates, gallates, etc.
Chars slightly, acetone is evolved.		From acetates.
The residue contains a soluble alkaline carbonate.		Organic compounds of NaOH, KOH, etc.
The residual carbonate is insoluble in water.		Organic salts of the alkaline earths, etc.
6. It does not change colour.		Most salts of the alkalis, certain salts of the alkaline earths, as chlorides and nitrates.
7. Fumes are evolved and a sublimate is formed.		Compounds of NH_4, Hg, As, Sb, also S, I, $SnCl_2$ and $CdCl_2$. $PbCl_2$ sublimes at a high temperature. Oxalic, benzoic and succinic acids.
(*a*) ***It sublimes without fusing.***		
The sublimate is white.		NH_4 salts.
The sublimate is yellow when hot, white when cold.		Hg_2Cl_2.

Results.	*Inference*
A sublimate of white octohedral crystals.	As_2O_3.
White quadrilateral prisms.	SeO_2.
(b) ***The substance fuses and yields a white sublimate.***	
Melts readily and evolves heavy fumes ; white crystalline sublimate.	$HgCl_2$.
Fuses, changes to yellow ; at a red heat : sublimate of white acicular crystals.	Sb_2O_3.
At a high temperature : a dark yellow fluid sublimate	$PbCl_2$.
Bright scales sublime ; fuses to a reddish-yellow liquid at a high temperature.	MoO_3.
White scales and odour of frankincense.	Benzoic acid.
Silky needles and irritating fumes.	Succinic acid.
White fumes and white crystals.	Oxalic acid.
White amorphous sublimate.	TeO_2.
(c) ***The sublimate is yellow.***	
Yellow and red sublimate and green flame at mouth of tube.	P.
Reddish-brown drops, yellow when cold.	S and polysulphides.
(d) ***The sublimate is blue or black.***	
Blue.	Indigo.
Dull black, red when rubbed.	HgS.
Violet vapours are evolved and a metallic-looking blue-black crystalline sublimate is formed.	I. (Iodoform, etc.)
Confirm for Hg, As and Cd by heating some of the dry substance in an ignition tube with Na_2CO_3 and a little charcoal powder.	
Metallic globules or mirror.	Hg.
A black metallic mirror.	As.
A metallic mirror and brown sublimate.	Cd.
8. The substance readily fuses and gives off moisture.	Certain hydroxides and hydrates.
The moisture turns red litmus paper blue.	NH_4 compounds.
The moisture reddens blue litmus paper.	Free acids, such as HCl, HNO_3, H_2SO_3, H_2SO_4, etc., or of acid salts.
It also intumesces or swells up.	Salts with water of crystallization, *e.g.*, alums, phosphates, borates, etc.

Results.	*Inference.*
9. (*a*). **The substance gives off a colourless, odourless gas.**	
The gas re-inflames the glowing end of a match.	Oxygen from peroxides, chlorates, perchlorates, nitrates, bromates, and iodates; N_2O from NH_4NO_3.
It supports combustion.	N_2O from NH_4NO_3, or a nitrate in the presence of an ammonium salt.
The gas does not support combustion.	N from NH_4NO_2, or a nitrite in the presence of an ammonium salt.
The gas does not support combustion. Dip a glass rod into lime-water and lower it into the test tube; the lime-water becomes turbid.	Carbonates; oxalic, benzoic and succinic acids, etc.
Pass the gases through $Ca(OH)_2$ sol. The issuing gas burns with a blue flame.	CO and CO_2 from the decomposition of oxalic acid, oxalates, and formates.
(*b*) **The gas possesses odour.**	
The gas smells of NH_3 and turns red litmus paper blue.	Ammonium salts; from the cyanates in the presence of H_2O and from nitrogenous organic matter.
Confirm for NH_3 by warming the substance in a test tube with KOH solution.	
Smells like stale eggs and blackens paper moistened with lead acetate.	SH_2 from hydrated sulphides and hyposulphites in the presence of moisture.
A gas with a suffocating odour which reddens blue litmus paper.	SO_2 from sulphites; or hyposulphites, sulphates and from metallic sulphides and thiocyanates.
Confirm for SO_2 by lowering a rod moistened with K_2CrO_4 into the test tube, a green colour : SO_2.	
A gas with garlic odour, burns with a green flame.	PH_3 from phosphites and hypophosphites.
A fetid smell of CS_2.	Certain thiocyanates.
The odour of bitter almonds, and burns with a peach-coloured flame.	Cy from cyanides of Ag, Hg, Cu, Zn, and from cyanates and thiocyanates.

Results.	*Inference.*
Confirm for Cy, when CO_2 is also present, by passing the gases through lime-water and igniting the Cy.	
(*c*) **It gives off a coloured gas.**	
Brown fumes of N_2O_4 mixed with oxygen.	Nitrates of the heavy metals, such as Pb, Bi, etc.
A yellow-green gas with peculiar smell; bleaches litmus, and turns KI and starch paper blue.	Cl, from chlorides of Pt, Au, etc., also from certain chlorates and hypo-chlorites.
Brown fumes with peculiar odour.	Br from bromides and some bromates.
Brown fumes condensing to red liquid.	Chromyl chloride, from chloride and chromate.
Purple vapours and sublimate.	I from iodides and some iodates.
A vapour condensing to yellow or brown drops and burning with a blue flame.	S, from certain metallic per-sulphides, as PtS_2, Au_2S_3, Sb_2S_5, SnS_2, FeS_2, etc.
White fumes of HCl or SO_3.	From certain chlorides and sulphates.

Experiment II.—**Heat a little of the substance on charcoal before the blowpipe, in the outer flame.**

Results.	*Inferences.*
1. The substance decrepitates.	NaCl, KNO_3, $Pb2NO_3$, etc.
2. It deflagrates.	Nitrates, chlorates, bromates and iodates.
3. It fuses readily and is absorbed by the charcoal or forms a fluid bead.	Alkali salts and certain salts of the alkaline earths.
4. An infusible white residue is left, very luminous when strongly heated.	BaO, SrO, CaO, MgO, Al_2O_3, ZnO and SiO_2. Also ZrO_2, ThO_2, etc.
The residue turns moistened red litmus paper blue.	BaO, SrO, CaO, MgO.

Experiment III.—When the white infusible residue is cold, add a drop of Co_2NO_3 and again ignite strongly.

Results.	*Inferences.*
A blue coloured mass is left.	Al_2O_3, phosphates of Ca, Sr and Ba and many silicates.
A pale pink-coloured mass is left.	MgO.
A bluish green-coloured mass is left.	SnO_2.
A pale green-coloured mass is left.	ZnO, TiO_2.
A violet-coloured mass is left.	Phosphate of magnesia, $Mg_3(PO_4)_2$.
5. A coloured residue is left.	
The residue is black.	Fe, Ni, Co, Mn, Cr, Cu, etc.
And is attracted by the point of a magnetised pen-knife blade.*	Fe, Ni, Co.

Confirm.—Transfer the particles to a piece of filter paper laid on glass, add a drop of dil. HCl and of HNO_3. Dry carefully over a flame; a pale pink tint which turns to blue : Co. A greenish tint changing to yellow : Ni. Add a drop of K_4FeCy_6, a blue colour : Fe.

Experiment IV.—Prepare a clear colourless bead of borax in a ring or loop of platinum wire about 3 or 4 m.m. (or ⅛ inch) in diameter, then take up a small quantity of the powdered substance by dipping the hot bead into it and re-fuse.

1. Heat in the outer or oxidizing blowpipe flame.
2. Heat in the inner or reducing blowpipe flame.

Or the bead may be fused in the corresponding areas of the bunsen flame, but the results are not always satisfactory.

Colour of Bead.	*In the Oxidizing Flame.*	*In the Reducing Flame.*
Amethyst.	Mn, Di (Co mixed with Ni)	Ti, cold.
Blue.	Co, hot and cold; Cu cold.	Co, hot and cold; Nb.
Brown.	Ni hot and cold.	Mo.
Green.	Cr, Cu (hot), V (cold), U.	Fe, U, Cr, V.
Pink.	Di.	Di.
Red.	Ce, Fe; Ni (brown cold).	Cu (opaque when in excess)
White.	Ag, Zn.	Ag, Bi, Cd, Nb, Ni, Pb, Sb, Te, Zn.
Yellow to brown.	Fe; U, Pb, Bi, Sb, V, Mo (hot).	Ti, W, V, Mo (hot).
Colourless.	Ag, Al, Ba, Ca, Cd, Nb, Pb, Sb, SiO_2, Sn (turbid), Sr, Ta, Te, Ti, W, Zn.	Al, Ba, Ca, Ce, Cu, Di, Li, Mn, SiO_2, Sn, (turbid), Sr, Ta.

Confirm for Mn and Cr by fusing on Pt foil with Na_2CO_3 and KNO_3, a blue residue : Mn; a yellow residue : Cr.

*Magnetise the blade of a pen-knife by drawing a magnet over it 4 or 5 times in the same direction.

Experiment V.—Flame test.—Take up a little of the substance on a very thin platinum wire moistened with conc. HCl and heat it at the base of the bunsen flame.

Results.	*Inferences.*
The flame is coloured bright yellow.	Na.
,, ,, ,, yellowish-red.	Ca.
,, ,, ,, red.	Sr.
,, ,, ,, crimson.	Li.
,, ,, ,, pale green.	Ba and phosphates.
,, ,, ,, green.	Cu, B_2O_3.
,, ,, ,, deep green.	Tl.
,, ,, ,, vivid blue.	Cu.
,, ,, ,, bluish-grey.	As, Sb, Pb.
,, ,, ,, lavender.	K,
Confirm for borates; heat the substance, moistened with a little H_2SO_4 on a clean platinum wire : green colour.	
Confirm for K; view the flame through blue glass : lilac to red colour.	

Experiment VI.—Heat the substance on charcoal in the inner flame.

Results.	*Inferences.*
A white incrustation is formed on the charcoal.	$HgCl_2$.
A white incrustation far from the test and an odour of garlic is emitted.	As.
A white incrustation with slight acid odour.	Te.
A yellow incrustation when hot, white when cold.	Zn.
Confirm for Zn; moisten with Co2NO_3 and heat again : green colour.	Zn.
A reddish-brown incrustation readily volatilized.	Cd.
A dark red incrustation; an offensive odour as of decaying horse-radish.	Se.

Experiment VII.—**Mix with $NaKCO_3$ (fusion mixture) and KCy and heat on charcoal in the reducing flame.**

Alternative method.—Flatten out a small piece of Na, wrap the substance in it, and heat on charcoal before the blowpipe.

Scrape out, with a magnetised penknife blade, into a small mortar, grind with water; wash away the charcoal powder and examine for metallic particles.

Results.	*Inferences.*
It is reduced to the metallic state.	
(*a*)—***With incrustation***	
White malleable beads: slight yellow incrustation, white when cold.	Sn.
Bluish-white malleable beads which mark paper; pale yellow incrustation when cold.	Pb.
White brittle beads with acicular crystals of Sb_2O_3. Copious white fumes and incrustation.	Sb.
Pale reddish brittle beads, dark orange incrustation when hot, yellow when cold.	Bi.
(*b*)—***Without Incrustation***	
White malleable metallic beads.	Ag.
Confirm for Ag; dissolve in HNO_3, add a drop of HCl: white ppt. of AgCl, which darkens on exposure to light.	
Grey metallic particles; non-magnetic.	Pt.
Yellow metallic beads.	Au.
Malleable particles or beads of red metal	Cu.
Black metallic infusible powders; magnetic.	Fe, Ni and Co.
Test for S by scraping out some of the fused mass and placing it on a silver coin with a drop of water: a black stain of AgS left.	S from sulphates or sulphites.

Experiment VIII—**Match test.—Hold a piece of crystallized $Na_2CO_3 10H_2O$ in the flame until it begins to fuse superficially, rub the untipped end of a wooden match in this until the wood is saturated with Na_2CO_3, char this end of the match and then dip it into the finely-powdered substance and heat it again in the upper reducing area of the bunsen flame. Grind the product with water in a mortar and search for metallic particles.**

Results.	*Inference.*
Malleable metallic beads—white.	Ag, Sn.
bluish-white.	Pb.
yellow.	Au.
red.	Cu.
Brittle metallic particles—white.	Sb.
pink tinge.	Bi.
Magnetic particles.	Fe, Co, Ni.
Confirm in each case by dissolving in acids and applying special tests.	

Experiment IX—Film test.—Heat the substance on a few fibres of asbestos, in the upper part of the bunsen flame so placed under a porcelain basin of cold water (supported on a retort stand) that any volatile matter may be condensed upon the cold porcelain.

In upper reducing flame.	*Upper oxidizing flame.*	*Inference.*
1.—*Metallic Film*	**2.[illegible]*ide Film***	
Grey Film		Hg.
Metallic lustre	White	As.
Black film	Yellow	Pb.
,, ,,	Brown	Cd.
,, ,,	White	Zn.
,, ,,	,,	Sn.
Velvety black	,,	Sb.
Black	Pale yellow	Bi.
,,	White	Te.
Cherry-red	,,	Se.

Experiment X—Expose the above films to the vapour of iodine by volatilizing some iodine from a few threads of asbestos, and afterwards to SH_2 or $(NH_4)_2S$. The film is coloured.

In upper reducing flame.	*Upper oxidizing flame.*	*Inference.*
3.—*Iodide Film*	**4.—*Sulphide Film***	
Red or yellow	Black	Hg.
	Yellow	As.
Yellow	Brown to black	Pb.
	Pale yellow	Cd.
	White	Zn.
	Brown or yellow	Sn.
	Orange	Sb.
	Yellow	Se.
Brown	Brown	Bi.
	Brown	Te.

Experiment XI—Boil some of the powder in a test tube with NaOH.

Results.	*Inference.*
Smell of NH_3 and white fumes of NH_4Cl when a rod moistened with HCl is lowered into the tube.	Presence of NH_4 salts.

PREPARATION OF THE SOLUTION.

Water.—Boil about ·5 gm. of the finely-powdered substance with distilled water, and decant the clear solution from any insoluble residue; repeat the process as long as anything is dissolved, ascertained by evaporating a drop of the solution in a watch-glass or on platinum foil. See Table of Solubilities.

Acids.—The residue insoluble in water is first treated with boiling dilute HCl. If insoluble in dil. HCl, try strong HCl, and if insoluble in this use HNO_3 upon a fresh portion of the substance. Notice whether CO_2, SO_2, HCy, or Cl are given off, also whether S, I, SiO_2, benzoic acid, etc., are precipitated. If insoluble in HNO_3 alone, add 3 vols. of strong HCl.

When aqua regia is used, employ it in successive small quantities; the iodide, bromide, cyanide, ferrocyanide, and ferricyanide of silver are decomposed by boiling with aqua regia.

The aqueous and acid solutions may be mixed and examined together; but they must be examined separately when it is wished to learn how the acids and bases are combined in a complex mixture.

Insoluble.—The residue insoluble in acids must be carefully washed with distilled water to remove acids, dried and tested by the Table for Insoluble Substances.

A residuum or precipitate may be due to the presence of sulphur or sulphides, iodine from iodides in the presence of oxidizing substances, or iodates in the presence of reducing agents; AgCl, Hg_2Cl_2, $PbCl_2$, $PbSO_4$, may have originally existed in the mixture or may have been formed by the action of acids; silicic, tungstic, titanic, and molybdic acids may have been set free from their compounds. If possible, discriminate between insoluble substances originally present and those which are precipitated on continued boiling with strong acids. See special Table for Insoluble Substances.

Insoluble cyanides—The presence of insoluble double cyanides may be suspected when HCy, although not found in the preliminary examination, is found on treating the substance with H_2SO_4. Examine by the Table for Insoluble Cyanides.

METALS AND ALLOYS.

If the substance be a metal or an alloy, first reduce it to filings or thin sheets; if very brittle it can be roughly powdered on an anvil with a hammer; to prevent the loss of fragments, wrap the substance in strong brown paper.

If it is not quickly dissolved by boiling **HCl**, it can be at once treated with HNO_3 of sp. gr. 1·2 (1:1 aq.), and if this act but slowly some strong HNO_3 of sp. gr. 1·4 can be added; if there still be a residue, filter and wash.

Solution.—May contain traces of Au and Sb, also As as oxide; other metals will be present as nitrates, and their examination can be proceeded with in the usual way, after evaporating off most of the HNO_3.

Residue.—May contain metallic **Au** and **Pt**, test for these separately; **Sb** and **Sn** as oxides or arsenates, **Pb2NO$_3$**, which is insol. in strong HNO_3, and **Bi** as arsenate or phosphate. If this residue be white then probably only Sn and Sb as oxides are present. Strong HCl converts metastannic acid into metastannic chloride which is soluble in water, but insol. in conc. HCl.

Boil the residue with a strong sol. of tartaric acid, and filter.

Residue—SnO_2. Reduce on charcoal with Na_2CO_3 and KCN: a white metal. Presence of **Tin.**	***Solution.***—Pass SH_2, an orange red precipitate: Sb_2S_3. Presence of **Antimony.**

To separate the other metals, treat with yellow $(NH_4)_2S$ and filter.

Residue—Bi_2S_3.	***Solution***—May contain **As, Sb, and Sn** as thio-salts, which can be detected in the ordinary way, see Group Table No. II. The P_2O_5 can be tested for in the solution after the removal of the S, Sn, Sb, and As, by warming with $(NH_4)_2MoO_4$.

EXAMINATION FOR BASES.—GENERAL TABLE.

To the solution add **HCl*** (if not already present) drop by drop till a ppt. is no longer produced, warm and filter, wash ppt. once with hot water. If crystals of $PbCl_2$ form, cool the solution before filtering.

<table>
<tr>
<td rowspan="5">Precipitate.
White.—
AgCl
$PbCl_2$
HgCl</td>
<td colspan="5">Filtrate.† Dilute with water, saturate with SH_2 gas, warm and filter, wash ppt. once with hot water.¶</td>
</tr>
<tr>
<td rowspan="4">Precipitate.
(a) Insol. in NaOH and yellow $(NH_4)_2S$.
PbS black
HgS black
Bi_2S_3 black
CuS black
CdS yellow

Ppt. (b) sol. in NaOH and yellow $(NH_4)_2S$.
SnS brown
SnS_2 yellow
Sb_2S_3 orange
Sb_2S_5 orange
As_2S_3 yellow
Au_2S_3 black
PtS_2 black</td>
<td colspan="4">Filtrate. Boil till free from SH_2, add a few drops of strong HNO_3.
If SiO_2 was found in preliminary examination soluble silicates may be in solution, evaporate to dryness.
If organic matter has been detected, evaporate to dryness, and burn it off.‡
Next add to the residue a few drops strong HCl and warm, add water and filter off the residue of insol. substances or carbon.
Test this solution for phosphates by placing two or three drops in a test tube and adding an equal vol. of strong HNO_3 and three times the bulk of Am_2MoO_4—warm, a yellow ppt. shows presence of H_3PO_4.
To the hot solution add NH_4Cl and a slight excess of NH_4OH, boil and filter quickly, wash once with hot water.</td>
</tr>
<tr>
<td rowspan="3">Precipitate.
$Fe(OH)_3$ brown
$Al(OH)_3$ white
$Cr(OH)_3$ green
also the phosphates of Gp. III, IV, V, and of Mg.</td>
<td colspan="3">Filtrate. Pass SH_2, warm, and filter, wash once with hot water.</td>
</tr>
<tr>
<td rowspan="2">Precipitate.
ZnS white
MnS pink
NiS black
CoS black</td>
<td colspan="2">Filtrate. Add NH_4OH and $(NH_4)_2CO_3$ warm§ and filter, wash once.</td>
</tr>
<tr>
<td>Precipitate.‖
$BaCO_3$ white
$SrCO_3$ white
$CaCO_3$ white</td>
<td>Filtrate.
Mg salts
K salts
Na salts
Li salts</td>
</tr>
<tr>
<td>Exam. by Table I.</td>
<td>Exam. by Table II.</td>
<td>Exam. by Table III or IIIA.</td>
<td>Exam. by Table IV.</td>
<td>Exam. by Table V.</td>
<td>Exam. by Table VI.</td>
</tr>
</table>

* When the solution has been made in dil. HCl, SH_2 can be passed at once. If strong HCl, HNO_3, or Aq. regia have been employed, evaporate off most of the acid and dilute with water before proceeding to the General Table. HCl will produce a ppt. in a saturated solution of a **Ba Salt,** and from **alkaline sols.** gelatinous H_4SiO_4, also crystalline **Boric, Benzoic,** and **Uric acids** from their salts. Amorphous, Sb_2O_5 and the sulphides of **As, Sb,** and **Sn** may be precipitated.

† If **As** or **Cr** has been detected in the preliminary examination, boil the sol. with H_2SO_3 or NH_4HSO_3 to reduce pentad **As** to triad **As,** and **chromates** to **Cr** salts; then boil the solution till free from SO_2. If a white ppt. should form here **(Ba, Sr, Pb sulphates)** filter off and examine the residue separately.

¶ A white ppt. of **S** may form; this can be removed by filtration.

‡ **Organic matter** such as sugar, citric, tartaric, oxalic acids prevent the precipitation of the metals of Group III.

§ Must not be boiled, because the NH_4Cl present would convert the carbonates into soluble chlorides.

‖ This ppt. may be dark coloured from the presence of PbS, as the ammonium carbonate often contains Pb as an impurity.

TABLE I.—SILVER GROUP.

Separation of the Metals precipitated by HCl.

<table>
<tr><td colspan="3">The precipitate may contain $PbCl_2$, AgCl, H_2gCl, also TlCl, HWO_4, H_3BO_3, H_4SiO_4, uric and benzoic acids; the oxychlorides of Bi, Sb, and Sn, unless sufficient HCl has been added and the solution warmed; $BaCl_2$ may be precipitated if too much HCl has been used. Wash the precipitate on the filter with hot water until all the $PbCl_2$ has been dissolved out.</td></tr>
<tr><td colspan="2">Residue. May contain AgCl, HgCl (also uric acid) : warm with excess of dilute $(NH_4)OH$; filter.</td><td rowspan="2">Filtrate. May contain $PbCl_2$.

On cooling, acicular crystals of $PbCl_2$ are deposited. To confirm add K_2CrO_4 sol.

A yellow ppt. of $PbCrO_4$.

Presence of Lead.</td></tr>
<tr><td>Residue. Is black. It contains free Hg and a double chloride of Hg and NH_4.

Confirm.—1. Dry and heat a portion of this with Na_2CO_3 in a bulb-tube.

A metallic mirror and globules indicate the presence of Hg, as a mercurous salt.

2. Diss. in aq. regia, nearly neutralize with Na_2CO_3, place a strip of bright Cu foil in the solution If Hg be present a grey deposit will form on the Cu, which looks like silver when rubbed.

Presence of Mercury.</td><td>Filtrate. May contain AgCl. Acidulate with dilute HNO_3.

A white curdy precipitate of AgCl is thrown down, which darkens on exposure to light, and is sol. in NH_4OH.

Presence of Silver.</td></tr>
</table>

TABLE II.—COPPER AND ARSENIC GROUPS.

Separation of the Metals precipitated by SH_2.

<table>
<tr><td colspan="6">The precipitate. May contain HgS, PbS, Bi_2S_3, CuS, CdS, SnS, SnS_2, Sb_2S_3, Sb_2S_5, As_2S_3 (Au and Pt must be specially tested for in a separate portion of the filtrate from Group I).* Wash the precipitate until free from HCl, warm for five minutes with NaOH or $(NH_4)_2S$. CuS is partly soluble in $(NH_4)_2S$, and HgS in Na_2S, hence in the absence of HgS use NaOH, and in absence of CuS employ $(NH_4)_2S$ but when both CuS and HgS are present extract with $(NH_4)_2S$; filter and pass SH_2 again, if more precipitate forms add it to the first precipitate.</td></tr>
<tr><td colspan="4">Residue. Test a small portion for Pb, if absent do not add H_2SO_4 and alcohol. Wash well, boil in a little HNO_3 (1 to 1 aq.) until action ceases, dilute, add dilute H_2SO_4 until all the Pb is precipitated as $PbSO_4$; cool, add an equal bulk of methylated spirit to complete the precipitation of the $PbSO_4$.</td><td colspan="2">Filtrate. May contain As, Sb, Sn (Au and Pt) as sulphur salts. Acidulate with HCl when As_2S_3, Sb_2S_3, SnS, and SnS_2 are reprecipitated. Filter, wash, and digest precipitate with a little strong HCl until SH_2 is no longer given off, add equal volume of water and filter.</td></tr>
<tr><td colspan="2">Residue. May contain HgS, $PbSO_4$ and free S; boil out the $PbSO_4$ with ammonium acetate; filter when cool.</td><td colspan="2">Filtrate. Boil off the spirit, add excess of $(NH_4)OH$; boil and filter.</td><td rowspan="2">Residue. Contains As_2S_3 (or S only).

Confirm (1) by reducing with Na_2CO_3 and KCN in a tube : metallic mirror and strong garlic odour.

(2) by Reinsch's test.

Presence of Arsenic.</td><td rowspan="2">Solution. May contain Sb and Sn. Place in a porcelain basin with a strip of Pt and of Zn.

1. A black stain on the Pt shows the presence of Antimony.

2. Scrape the deposit off the Zinc and diss. it in strong HCl (with Pt foil) add $HgCl_2$ sol. a grey or white ppt. indicates the presence of Tin.</td></tr>
<tr><td>Residue. May contain HgS and S, or S alone.
Confirm by heating the dried residue in a tube with Na_2CO_3.
A metallic mirror and globules indicate the presence of Hg as a mercuric salt.

Presence of Mercury.</td><td>Solution. Add K_2CrO_4 : a yellow precipitate of $PbCrO_4$.

Presence of Lead.</td><td>Precipitate. Consists of $Bi(OH)_3$. Dissolve in a little dilute HCl, and pour into a beaker full of water — a milkiness due to BiOCl forms after some time.

Presence of Bismuth.</td><td>Filtrate. If blue, Presence of Copper.

Add KCy until colourless, then pass SH_2. A yellow precipitate of CdS.

Presence of Cadmium.</td></tr>
</table>

*Se and the sulphides of Ru, Rh, Pd, Os, Te, Mo and Ir may also be present.

TABLE III.—IRON GROUP.

The Separation of the Metals, precipitated by NH_4OH in the presence of NH_4Cl.

(In the absence of Phosphates.)

<table>
<tr><td colspan="3">Precipitate may contain $Fe(OH)_3$ (brown), $Cr(OH)_3$ (green), and $Al(OH)_3$ (white).* Wash, dissolve in dil. HCl, add NaOH sol. (free from Al_2O_3) in excess, and boil for three or four minutes. Dilute, filter.</td></tr>
<tr><td colspan="2">Residue. May contain $Fe(OH)_3$ and $Cr(OH)_3$. Dry and fuse with Na_2CO_3 and KNO_3, on platinum foil. A bluish-green colour indicates the presence of some Mn. Boil with aq., and filter.</td><td rowspan="2">Solution.— Acidulate with dilute HCl, and add NH_4OH in slight excess.

A white gelatinous ppt.

Presence of Aluminium.</td></tr>
<tr><td>Residue. Dissolve in dilute HCl, and add K_4FeCy_6.

A ppt. of Prussian blue : Presence of Iron.

Test the original HCl solution for ferrous and ferric iron by means of K_3FeCy_6 and NH_4CNS.</td><td>Solution, yellow : Cr.

Confirm by adding acetic acid and lead acetate : yellow ppt. of $PbCrO_4$

Presence of Chromium.</td></tr>
</table>

* The following may also be present :—$Be(OH)_2$, $Sc(OH)_3$, $Y(OH)_3$, $Yb(OH)_3$, $Ce(OH)_3$, $La(OH)_3$, $Zr(OH)_4$, $Th(OH)_4$, H_2TiO_3, H_3TaO_4, and H_3NbO_4.

TABLE IIIA.—FOR THE SEPARATION OF PHOSPHATES, ETC.

The **precipitate** produced by NH_4Cl and NH_4OH when P_2O_5 is present may consist of **Fe, Cr,** and **Al as hydroxides** and of **Fe, Cr, Al, Mn, Ni, Co, Zn, Ba, Sr, Ca, Mg, as phosphates.** Dissolve in **dil. HCl,** neutralize with solid Na_2CO_3 till a permanent ppt. is **about** to form, then add a solution of **Na acetate** and **acetic acid** (**Fe, Cr** and **Al hydroxides and phosphates are insoluble** in acetic acid). Boil ; filter hot.*

<table>
<tr>
<td rowspan="5">Precipitate. Contains the phosphates of Fe, Cr, and Al. Treat as usual by Table III.

A. See footnote †</td>
<td colspan="5">Solution. May contain Phosphates of Groups IV, V, and of Mg. Remove the phosphoric acid by adding FeCl₃ drop by drop as long as a ppt. is formed‡ and until the solution acquires a faint red colour. Dilute and warm on a sand bath for some minutes (ferric acetate is converted into FePO₄). Filter hot and wash with hot aq.</td>
</tr>
<tr>
<td rowspan="4">Precipitate. FePO₄ and basic ferric acetate, due to the added FeCl₃.</td>
<td colspan="4">Solution. Add a drop of FeCl₃. If a ppt. forms, boil and filter again. Add NH₄Cl and NH₄OH ; filter.</td>
</tr>
<tr>
<td rowspan="3">Precipitate. Hydroxides. Examine by Table III for Fe, Cr, and Al.

B. See footnote †</td>
<td colspan="3">Solution. Pass SH₂ and filter.</td>
</tr>
<tr>
<td rowspan="2">Precipitate. Examine by Table IV for Co, Ni, Mn, and Zn.</td>
<td colspan="2">Solution. Add (NH₄)₂CO₃, and warm gently.</td>
</tr>
<tr>
<td>Residue. Examine by Table V for Ca, Sr, and Ba.</td>
<td>Solution. Add Na₂HPO₄ and stand for five minutes, a white ppt. of MgNH₄ PO₄.

Presence of Magnesium.</td>
</tr>
</table>

* The P_2O_5 may also be removed by adding **Tin** filings and HNO_3 to the ppt. in a dish. Boil and evaporate, with constant stirring, almost to dryness, dilute and filter, pass SH_2 through the sol. and filter to remove any traces of tin, and examine the filtrate by **Tables III, IV,** and for **Mg** as usual.

† If a ppt. is not obtained in A, Fe, Cr, and Al need not be looked for in B.

‡ If the first drop or two does not produce a ppt., do not add more, as all the phosphoric acid has been removed, and the metals are now present as chlorides.

TABLE IV.—NICKEL GROUP.

Separation of the Metals precipitated by NH_4SH, or by SH_2 in presence of NH_4OH.

<table>
<tr><td colspan="4">The precipitate may contain ZnS (white), MnS (pinkish), NiS (black), CoS (black).* Wash. Dissolve the ppt. in dil. HCl, if the ppt. is black, add a fragment or two of $KClO_3$ and boil. When dissolved add NaOH in excess, boil, and filter.</td></tr>
<tr><td colspan="3">Precipitate. May contain $Mn(OH)_2$, white to brown, $Co(OH)_2$, dark olive green, and $Ni(OH)_2$, light green. Wash, dissolve in a few drops of dil. HCl; nearly neutralize with NH_4OH; add excess of ammonium acetate; pass SH_2 for two minutes through the solution and filter.</td><td rowspan="3">Filtrate. May contain Zn, as $Zn(NaO)_2$. Pass SH_2. A white ppt. of ZnS :</td></tr>
<tr><td colspan="2">Precipitate. Boil with HCl and a few fragments of $KClO_3$; nearly neutralize with solid Na_2CO_3; add KCN solution so as just to redissolve the ppt. first produced. Boil for three or four minutes. Cool (filter off any slight ppt.), and add a strong solution of NaOCl† or of bleaching powder, warm gently until no further black ppt. forms; filter, and wash once.</td><td rowspan="2">Filtrate. May contain manganese as acetate. Add NH_4Cl, NH_4OH and pass SH_2, a flesh-coloured ppt. : MnS.

Confirm with borax bead, an amethyst colour :</td></tr>
<tr><td>Precipitate. Black : $Ni(HO)_3$.

Confirm by borax bead, a yellowish to sherry-red bead :</td><td>Filtrate. May contain cobalt as K_3CoCy_6. Evaporate a small part to dryness and test the residue in a borax bead. A blue bead :</td></tr>
<tr><td>Presence of Nickel.</td><td>Presence of Cobalt.</td><td>Presence of Manganese.</td><td>Presence of Zinc.</td></tr>
</table>

* $(UO_2)S$, InS and Tl_2S may also be present.
† Bromine or chlorine water and NaOH may be used instead of NaOCl.

TABLE V.—BARIUM GROUP.

Separation of the Metals precipitated by $(NH_4)_2CO_3$.

The precipitate may contain **$BaCO_3$, $SrCO_3$, $CaCO_3$**. Wash. Dissolve in warm **dil. acetic acid.** Warm a small portion of the solution with **K_2CrO_4**; if a ppt. is not formed, do not add **K_2CrO_4** to the main portion. If a ppt. be formed add **K_2CrO_4** to the whole in slight excess, warm and filter.

Precipitate. Yellow, **$BaCrO_4$**. Presence of **Barium.**	**Solution.** Add **$(NH_4)_2SO_4$** or dil. **NH_4OH** and **H_2SO_4**, warm and allow to stand for ten minutes. If a large ppt. forms it may be due to the presence of much Ca, therefore filter it off and warm it with $(NH_4)_2SO_4$ and NH_4OH. Filter.	
	Precipitate. Granular, **$SrSO_4$**. Heat ppt. with HCl, on Pt. wire, fleeting crimson flame : Presence of **Strontium.**	**Solution.** Dilute and add **ammonium oxalate**, a white ppt. of **Ca. oxalate.** Heat with HCl on Pt. wire, a steady red flame : Presence of **Calcium.**

TABLE VI.

Separation of the Magnesium Group.

To the filtrate from Group V add two drops of **$(NH_4)_2C_2O_4$** and two of **$(NH_4)_2SO_4$**, warm and filter. This is to remove any unprecipitated Ba, Sr or Ca. The solution may contain **Mg, K, Na,** and **Li** (also NH_4 salts added in the course of the analysis). Divide into two unequal portions.

A.—Small Portion.	B.—Large Portion.
Add **NH_4Cl, NH_4OH,** and **Na_2HPO_4**, warm, stir well with a glass rod and allow it to stand for a short time. A white **crystalline** precipitate of **$MgNH_4PO_4$**. (See note.) Presence of **Magnesium.**	Evaporate to dryness and ignite on perfectly clean platinum foil until all NH_4 salts have been expelled. A **yellow** flame indicates the Presence of **Sodium.** A **lilac** or **violet** flame when seen through blue glass or an indigo prism : K **Confirm.** Add 5 drops aq., 1 of HCl, and 5 drops $PtCl_4$, evaporate until nearly dry, and extract with alcohol. A yellow crystalline residue of K_2PtCl_6 : Presence of **Potassium.** A crimson flame : Presence of **Lithium.**

Sometimes when Mn is not completely precipitated in Group IV, it may be thrown down as phosphate and be mistaken for $MgNH_4PO_4$.

THE EXAMINATION FOR ACIDS.

(Acid Radicles or Anions.)

After the bases have been detected, refer to the Table of Solubilities (see index) to ascertain what acids form insoluble compounds with the bases present—all such acids must necessarily be excluded if the substance is a soluble one.

The acids, unlike the bases, cannot all be detected and separated in systematic order; the presence of each acid must be confirmed by its most characteristic special tests. Several of the acids should have been detected during the preliminary examination when testing for the bases, *e.g.*, CO_2, SH_2, H_2SO_3, $HClO$, $HC_2H_3O_2$, H_3AsO_3 and many others.

The presence of such organic acids as tartaric, citric, benzoic and succinic, should also have been more or less definitely ascertained.

PRELIMINARY TESTS FOR ACIDS.

1. Warm the powder in a test-tube with dilute HCl.

Results.	*Inference.*
Gases are given off—	
A colourless gas with but faint smell is evolved, which renders lime-water turbid. Use a glass rod for the $Ca(OH)_2$.	CO_2, from carbonates, and from cyanides and cyanates containing carbonates
Ditto, having the suffocating odour of burning sulphur. Turns $K_2Cr_2O_7$ sol. green.	SO_2, from sulphites.
Ditto, with separation of sulphur.	SO_2, from thiosulphates.
Ditto, with odour of stale eggs, and blackens lead acetate paper.	H_2S, from sulphides, except Au_2S_3, PtS_2, Ag_2S, HgS, CuS, Bi_2S_3, and As_2S_3; these however give off H_2S in presence of zinc and HCl.*
Ditto, with the odour of bitter almonds.	HCN from cyanides.
Reddish-brown fumes.	NO and NO_2 from nitrites.
A yellow-green gas, of suffocating odour, which bleaches indigo and other vegetable colours.	Cl, from hypochlorites.

* S in insol. sulphides and sulphates is best detected by the match and silver coin tests.

2. Warm a portion of the substance with H_2SO_4 (1 *acid to* 1 *water*).

Results.	*Inference.*
***Gases are given off*—**	CO_2, H_2S, SO_2, NO, and HCN, have already been detected by means of dil. HCl.
Smell of vinegar.	Acetates.
Add 1 c.c. alcohol : ethyl acetate odour.	Ditto.
Strong acid fumes.	HCl, HF (HCN from ferro- and ferricyanides) $H_2S_2O_3$, HClO, HCNO.

3. Warm with a few drops of conc. H_2SO_4 (the heat must not be sufficient to drive off the H_2SO_4).

***Colourless gas evolved*—**	
With irritating odour, gives white fumes with NH_3. Add MnO_2 : Cl.	HCl.
Corrodes glass.	HF.
CO evolved without blackening.	Formic acid.
CO and CO_2 evolved. Absorb CO_2 by $Ca(OH)_2$ and burn the CO.	Oxalic acid.
Peculiar odour, mixture of H_2S, SO_2 and HCN with precipitation of S; fumes redden paper moistened with $FeCl_3$.	Thiocyanates.
CO, CO_2, SO_2 and odour of burnt sugar; the substance also blackens, tartaric acid chars rapidly, citric but slowly.	Tartaric and citric acid.
The gas re-ignites a glowing splinter.	Oxygen from chromates, permanganic acid, peroxides, and other easily decomposed compounds rich in oxygen.
***Coloured gases are evolved*—**	
Violet vapours which turn starch paper blue.	Iodides (and iodates in presence of reducing agents).
Reddish-brown vapours which turn starch paper yellow.	Bromides and bromates.
Greenish-yellow gas with small explosions.	Chlorates.
Brownish-yellow irritating vapours.	Nitrates.
Confirm for HNO_3 by adding fragments of Cu : red fumes.	

N.B.—In treating with acids, amongst the substances which may separate out are the following :—

Results.	*Inference.*
White sulphur (with H_2S).	From polysulphides.
Yellow ,, (with SO_2).	From thiosulphates, polythionates.
Iodine	From iodides in presence of oxidizing, and from iodates in presence of reducing bodies.
Colourless gelatinous silica.	From silicates.
Confirm for SiO_2 by microcosmic salt bead.	
Yellow (when hot) tungstic acid.	Tungstates.
White molybdic acid, soluble in an excess of acid.	Molybdates.
White TiO_2.	Titanates.
Confirm by adding a fragment of Zn and diluting—	
Violet colour :	Titanic acid.
Blue turning to brown :	Tungstic acid.
Blue-green turning to brown :	Molybdic acid.
Boracic, benzoic, succinic, uric, and other acids separate out from concentrated solutions.	

PREPARATION OF THE SOLUTION.

As many of the bases interfere with the reactions of the acids, it is necessary to remove them before proceeding to test for the latter.

Therefore boil a portion of the original substance with **pure** Na_2CO_3 (free from SO_4 and Cl) which precipitates nearly all the metals, except the alkalis, as carbonates ; filter and add to the filtrate a few drops more Na_2CO_3, if no further precipitate is thrown down boil the solution, now containing all the acids as salts of sodium.

But if H_3AsO_3, H_3AsO_4, H_2MoO_4, H_2WO_4, H_2SeO_4, H_2TeO_4 or H_2CrO_4 have been found amongst the bases, first pass the SH_2 through the slightly acid solution and filter ; warm the filtrate to drive off excess of SH_2 and neutralize with NH_4OH, and then remove any bases of Groups III, IV and V by Na_2CO_3, as before.

Divide the solution into 4 parts.

(*a*) **Acidify one portion with dilute HCl.**
(*b*) **Acidify another portion with dilute HNO_3.**
(*c*) **Acidify the third portion with dilute $HC_2H_3O_2$.**
(*d*) **Neutralize the fourth portion with dilute $HC_2H_3O_2$.**

(*a*). HCl Solution.

1. Add $BaCl_2$ sol.	
a. A white ppt. insol. in boiling HCl	: H_2SO_4.
b. Filter, if necessary, and add **Br aq.**, a white ppt.	: H_2SO_3 or $H_2S_2O_3$.
c. A white gelatinous ppt. which evolves SiF_4, on warming with H_2SO_4	: H_2SiF_6.
2. Add $FeCl_3$ sol.	
a. A blood-red colour, destroyed by $HgCl_2$	: HCyS.
b. A dark-blue ppt. (Prussian blue.)	: H_4FeCy_6.
c. A brown or green solution	: H_3FeCy_6.
Confirm for H_3FeCy_6 by $FeSO_4$: deep blue ppt. If both H_4FeCy_6 and H_3FeCy_6 are present, filter off the ppt. reduced by $FeCl_3$ and add H_2SO_3 to the filtrate, a blue ppt.	: H_3FeCy_6.

(*b*). HNO_3 Solution.

Add $AgNO_3$ sol.	
A white or yellowish ppt. sol. in **NH_4OH** : AgCl, AgBr, AgCy, $AgBrO_3$ or $AgIO_3$.	
a. AgCl (white). **Confirm** by MnO_2 and H_2SO_4, Cl evolved, which bleaches litmus paper.	: HCl.
b. AgBr (yellowish). **Confirm** by MnO_2 and H_2SO_4 : red fumes, or by Cl and CS_2 : red-brown colour.	: HBr.
c. AgCy (white). **Confirm** by igniting on porcelain, metallic silver is left.	: HCy.
d. $AgBrO_3$ (white), crystalline.	: $HBrO_3$.
e. $AgIO_3$, white ; H_2SO_3 converts it into yellowish AgI	: HIO_3.

(*c*). Acetic Acid Solution.

1. Add $CaCl_2$ sol.

A white ppt. This may be due to **HF, $H_2C_2O_4$** or **H_4FeCy_6**.

2. **Add $AgNO_3$ sol.**

A pale yellow or white ppt. insol. in NH_4OH.

a. AgI. Warm with MnO_2 and H_2SO_4, violet vapours. Add Cl aq. and CS_2 : purple sol. : HI.

b. A white ppt. of AgCyS : HCyS.

c. A reddish-brown ppt. : H_3FeCy_6.

d. A black ppt. Test the original sol. with Na nitroprusside : a violet colour : SH_2 or a soluble sulphide.

(*d.*) Neutral Solution.

1. **Add $AgNO_3$ sol.**

I. A white ppt. sol. in NH_4OH.

a. From strong sols. : H_3BO_3.

b. The original sol. does not coagulate albumen : $H_4P_2O_7$.

c. The original sol. coagulates albumen : HPO_3.

d. The ppt. becomes grey on boiling : H_2SO_3.

e. The ppt. blackens on boiling : $H_2S_2O_3$.

f. On warming becomes grey : Oxalic and malic acids.

Malic acid yields a white ppt. with $Pb2C_2H_3O_2$, which melts on boiling the liquid.

g. On warming : metallic mirror : $HCHO_2$.

h. The sol. in NH_4OH on warming yields a mirror. The original sol. (neutral) : a ppt. with $CaCl_2$: Tartaric acid.

Tartaric and Citric Acids.—Precipitate the tartaric acid by a strong sol. of K acetate in alcohol, add acetic acid, stir well and allow to stand. Filter off the $KHC_4H_4O_6$—boil off the alcohol and add BaH_2O_2 or Ba acetate : a white ppt. : Citric acid.

Other acids also give white ppts., *e.g.*, thiocyanic, hydroferrocyanic. See (*b*) HNO_3 solution.

II. A coloured ppt. sol. in NH_4OH.

a. Yellow. **Confirm** for P_2O_5 by $(NH_4)_2MoO_4$: H_3PO_4.

b. Pale yellow : H_3AsO_3.

c. Brown : H_3AsO_4.

d. Red : H_2CrO_4.

e. Orange : H_4SiO_4.

2. **Add $FeCl_3$ sol.**

a. A red colour, destroyed by boiling and a brown basic salt precipitated	: $HCHO_2$ and $HC_2H_3O_2$.
b. A violet-red colour destroyed by boiling	: $H_2S_2O_3$.
c. A pale yellow ppt. of basic ferric benzoate	: Benzoic acid.
d. A reddish brown ppt. of basic ferric succinate	: Succinic acid.

To distinguish between benzoic and succinic acids.—Boil the mixed precipitate with NH_4OH, filter, add alcohol and $BaCl_2$, white Ba succinate is thrown down. Benzoic acid does not give a precipitate.

To detect HCN in the presence of HCl, wash the Ag precipitate obtained in the HNO_3 sol. (*b*) and ignite on a piece of porcelain. Dissolve the metallic Ag left by the AgCN in nitric acid, and test for Ag in the solution with HCl as usual.

To detect HBr in the presence of HCl.—Distil the dried chloride and bromide with $K_2Cr_2O_7$ and H_2SO_4. Remove the Br from the chromyl chloride in the distillate by means of ether.

To detect HCl in the presence of HI.—Digest the mixed AgI and AgCl ppts. with NH_4OH, filter; the AgI is insoluble. Dilute HNO_3 reprecipitates the AgCl from the filtrate.

The pale yellows of AgI and AgBr are not always visible when mixed with white precipitates, hence very little importance can be attached to the colour of the precipitate obtained on adding $AgNO_3$.

To distinguish between HCl, HBr, and HI.—Precipitate the HI as Cu_2I_2 by means of $CuSO_4$ and H_2SO_3; filter, remove the $CuSO_4$ by pure NaOH, evaporate the filtrate to dryness, and test for Cl by $K_2Cr_2O_7$ and H_2SO_4, and for Br by Cl water and ether, $CHCl_3$ or CS_2. Or dissolve out the AgCl by boiling with $(NH_4)_2CO_3$; add a little Cl water and starch paste to the residue, a blue colour : **iodine.** To another part add an excess of Cl water to oxidize the iodine, shake with CS_2, a brown colour : **bromine.**

To distinguish between chloride and chlorate.—Precipitate the chloride by $AgNO_3$, filter off the AgCl. Reduce the chlorate to chloride by zinc and H_2SO_4, then add $AgNO_3$: AgCl.

To distinguish between HCl, HBr, HI and HCN.—Test for HCN by treating the mixture in a dish with dilute H_2SO_4, covered with an inverted porcelain dish containing a drop of $(NH_4)_2S$ or $AgNO_3$, to absorb the HCN; the NH_4CNS formed will give the blood-red colouration with $FeCl_3$, and the $AgNO_3$ a white precipitate of AgCN.

A white or slightly yellow precipitate may contain silver salts of HCl, HBr, HI, HCN, H_4FeCy_6, HIO_3, $HBrO_3$; and if orange, H_3FeCy_6 in addition.

To distinguish between hypochlorites and chlorates.—Add NaOH and then $MnSO_4$: brown ppt. of $MnO_2.H_2O$, due to the oxidation by the hypochlorite. Filter, and decompose the NaCl thus formed in the solution from the hypochlorite by $AgNO_3$ sol. Filter off the AgCl and add Zn and H_2SO_4 to the filtrate (to reduce the chlorate to a chloride), filter and add $AgNO_3$, a white ppt. of AgCl indicates the former presence of a chlorate.

To distinguish alkaline cyanides, ferrocyanides, ferricyanides and thiocyanates.—Saturate with CO_2 and distil off the HCy ; add excess of $FeCl_3$ to the residue in the flask, a precipitate of Prussian blue : **ferrocyanide.** Filter, a red filtrate shows the presence of **thiocyanates** ; add $FeSO_4$: a precipitate of Turnbull's blue : **ferricyanide.**

Cyanide, chloride, bromide, iodide, ferrocyanide, ferricyanide, and thiocyanate.—Precipitate with $AgNO_3$, filter and ignite ppt. (all except the haloid compounds are decomposed). Fuse the ignited ppt. with Na_2CO_3, digest with boiling water and test the solution for Cl, Br, and I in the usual way.

To detect a soluble **sulphide, thiosulphate, sulphite and sulphate** in a mixture. Add $CdCO_3$ and agitate, extract with dil. acetic acid and filter.

<table>
<tr><td rowspan="3">A residue of CdS (yellow) indicates the presence of a soluble sulphide.</td><td colspan="3">Filtrate. Add $BaCl_2$ to the cold solution.</td></tr>
<tr><td colspan="2">Precipitate : $BaSO_4$ and $BaSO_3$, warm with dil. HCl and filter.</td><td rowspan="2">Filtrate contains thiosulphates. Add HCl and warm, a white ppt. : thiosulphate.</td></tr>
<tr><td>Residue. $BaSO_4$: sulphate.</td><td>Filtrate. Add Cl water, a white ppt : sulphite</td></tr>
</table>

To detect a soluble sulphide in the presence of free SH_2, add a drop or two of Na nitroprusside : a purple colour.

INSOLUBLE SUBSTANCES.

The residue left after treatment with HCl and HNO_3 may contain the following:—Carbon and chrome-iron (black), sulphur, AgI and $PbCrO_4$, (yellow); certain double cyanides, SiO_2 and most silicates, AgCl, AgBr, $PbCl_2$, $PbSO_4$, SnO_2, Sb_2O_4, $BaSO_4$, $SrSO_4$, $CaSO_4$, CaF_2 and other fluorides, certain arsenates and metaphosphates (white). Ignited Al_2O_3 (white), Cr_2O_3 (green), and Fe_2O_3 (brown). A few of the above are slightly soluble in acids and should have been already found in the solution, *e.g.*, $PbCl_2$, $PbSO_4$, $PbCrO_4$, Fe_2O_3, $CaSO_4$, fluorides, arsenates and some others.

PRELIMINARY TESTS.

a. **The insol. residue is white.**

1. Moisten with $(NH_4)_2S$ solution, it blackens : **Ag, Pb** salts.

2. Heat in an ignition tube, it fuses : **Ag and Pb** salts. It is **infusible** and remains **white : SiO_2, ($PbSO_4$), Al_2O_8, $BaSO_4$, $SrSO_4$, $CaSO_4$, CaF_2.**

3. Exposed to sunlight it becomes slate-coloured : **AgCl.**

4. **Confirm** for Pb and Ag by the blowpipe on charcoal : white malleable beads.

5. **Confirm** for SiO_2 in the microcosmic salt bead; a skeleton of **SiO_2** : silicates.

6. **Confirm** for Al_2O_3 by heating on platinum wire with $Co2NO_3$ solution ; a blue residue : **Al_2O_3.**

7. **Confirm** for Ba, Sr, and Ca, by the flame test with HCl; apple-green colour : Ba ; crimson : Sr ; brick-red : Ca.

b. **The insol. residue is yellow.**

Heat in an ignition tube; it fuses, SO_2 evolved and yellow drops sublime : **S.** Infusible, darkens on heating : **SnO_2, Sb_2O_4.**

Confirm for Sn and Sb on charcoal or by match test; malleable beads : Sn ; brittle hard beads : Sb.

c. **The residue is green.**

Fuse in borax bead ; green colour : Cr_2O_3.

d. **The residue is brown or black.**

Infusible, leaves magnetic residue when heated on charcoal : Fe_2O_3.

Black residue burning entirely away. **Confirm** by igniting with KNO_3 on Pt foil; it scintillates : C.

TREATMENT OF THE INSOLUBLE RESIDUE.

1. If C or S has been detected, the residue must be ignited in an open crucible.

2. Certain substances, if present, may be dissolved out by special reagents, and tested for separately, viz. :—

AgCl, AgBr, AgI, soluble in strong KCy.
$PbCl_2$ soluble in boiling water.
$PbSO_4$ soluble in ammonium acetate.

3. The dry residue is mixed with four times its bulk of fusion mixture (Na_2CO_3,K_2CO_3) and fused in a Pt crucible (or on a piece of Pt foil turned up at the edges) over a bunsen burner until all effervescence ceases.

4. If compounds of easily reducible metals (Ag, Pb, Sb, Bi, etc.) are present, they must first be removed by suitable solvents, because the above metals form easily fusible alloys with Pt; or the fusion may be made in a small porcelain crucible, on a crucible lid, or on a piece of a broken porcelain dish. The silica of the porcelain is attacked by the fusion mixture, hence if SiO_2 has been indicated in the preliminary tests, fuse on Pt after removing the Ag, etc. A nickel crucible can be used in most cases.

Dissolve the fused mass in hot water. Filter.

<table>
<tr><td colspan="2">Residue. Contains the bases.
(a). If Ag or Pb has been found extract with HNO_3.
(b). If Ag and Pb are absent, extract with HCl.
Filter and wash.</td><td colspan="2">Filtrate. Contains the acids.
Neutralize with HNO_3 and boil. If SiO_2 be present, evaporate to dryness, take up with HNO_3 and filter hot.</td></tr>
<tr><td>Residue.
SnO_2, Sb_2O_4, CaF_2, and chrome iron.
Confirm for each by special tests.</td><td>Filtrate.
Ag, Pb, Sn, Sb, Al, Fe, Cr, Ba, Sr, Ca.
Examine by the Tables in the usual way.</td><td>Residue.
SiO_2.</td><td>Filtrate. Examine for acids. HCl, HBr, HI, H_2SO_4, H_2CrO_4, H_3PO_4, H_3AsO_4, HF, all of which should have been found in the preliminary tests.</td></tr>
</table>

DETECTION OF ALKALIS IN SILICATES.

Mix ·5 gram of the finely-powdered silicate with 2 grams of NH_4F and a little strong H_2SO_4 to a paste on platinum foil; heat at a very low temperature as long as fumes of SiF_4 are evolved, then raise the heat to drive off the H_2SO_4. Dissolve the residue in water and test for alkalis on Pt. wire in the usual way.

A second method is to grind ·5 gm. of the already finely-powdered mineral with ·1 gm. NH_4Cl and 4 gms. pure $CaCO_3$; then heat to bright redness on platinum foil for 20 to 30 minutes. When cold, boil crucible and contents in about 50 c.c. water, filter (the residue consists of CaO, SiO_2, etc., and need not be examined), to the **solution** add $(NH_4)_2CO_3$ to precipitate the $CaCl_2$, filter and wash, evaporate the filtrate to dryness and test for the alkalis in the usual way.

TREATMENT OF INSOLUBLE DOUBLE CYANIDES.

The simple cyanides are converted into chlorides by boiling with strong HCl, but AgCN, Ag_4FeCy_6, and Ag_3FeCy_6 require to be boiled with aqua regia.

To detect an insoluble cyanide boil some of the residue insoluble in HCl (left by the original substance) with NaOH, filter, acidulate the filtrate with HCl and test it for H_4FeCy_6 and H_3FeCy_6; if either are present, proceed as follows :—

a. Boil one part of the substance with NaOH; filter.

Residue.— Diss. in HCl and examine for bases in the usual way, except Na, K.	**Solution.**—May contain H_4FeCy_6 and H_3FeCy_6; also such bases as PbO, ZnO, and Al_2O_3 soluble in NaOH. Pass SH_2 to remove PbO and ZnO, filter, and test filtrate for H_4FeCy_6 and H_3FeCy_6 with $FeCl_3$ and $FeSO_4$.

b. Fuse another portion with four times its bulk of a mixture of one part NH_4NO_3, and three parts $(NH_4)_2SO_4$. Dissolve the melt in HCl, remove heavy metals in the usual way, and test for K and Na.

Test for acids in the solution as in *a.*

APPENDIX.

TESTS FOR CERTAIN ELEMENTS IN CARBON COMPOUNDS.

(See also Preliminary Tables, p. 82 and p. 101.)

To detect hydrogen, nitrogen, sulphur, &c., in carbon compounds :—

1. **Hydrogen.**—Mix the substance with dry CuO and heat in an ignition tube, water is given off and condenses in the cooler part of the tube : Hydrogen.

2. **Carbon.**—The gas given off renders lime-water turbid (a drop of $Ca(OH)_2$ on the end of a glass rod is sufficient) : CO_2 from Carbon.

3. **Nitrogen.**—Its presence may be indicated by the odour of singed feathers when the substance is burnt. Mix the powdered substance with soda-lime and heat in an ignition tube, the odour of NH_3 : Nitrogen. NO_2 compounds do not give off NH_3.

4. **Sulphur and Phosphorus.**—1. Mix with pure Na_2CO_3 and pure KNO_3 or with Na peroxide and fuse in an ignition tube, dissolve out with water and test for H_2SO_4 by $BaCl_2$, and H_3PO_4 by am. molybdate. 2. Ignite with a very little **metallic Na,** and dissolve in aq. Add a drop of Na nitroprusside to the clear sol., a purple colour : Sulphur.

5. **The Halogens.**—1. Heat a copper wire in the bunsen flame until it ceases to give a green colour to the flame, then dip it into the substance to be tested, a vivid blue flame indicates the **presence of a halogen.** 2. Mix with pure CaO, heat in an ignition tube, dissolve out with water, filter and test for HCl, HBr and HI in the usual way.

TESTS FOR CERTAIN ORGANIC LIQUIDS.

Heat a drop or two in a dry test tube.

Results.	*Inference.*
It volatilizes completely.	
The vapour is non-inflammable, pleasant ethereal odour	Chloroform.
The vapour burns with a pale blue flame	Alcohol, Aldehyde, Chloral, Carbon bisulphide.

Results.	*Inference.*
The vapour burns with pale blue flame, with slight charring and unpleasant odour	Glycerol.
The vapour burns with luminous flame	Ether, Et. acetate, nitro-benzene.
The vapour burns only on warming, smoky luminous flame	Paraffin oils, turpentine, benzene, aniline.
The vapour is acid, pungent and inflammable	Formic or acetic acids.

TABLE OF SOLUBILITIES.

1. All the salts of Li, NH_4, Na, and K are soluble in water.

2. All normal nitrites, nitrates, hypochlorites and chlorates are soluble in water. If a compound is soluble in water it is usually soluble in dilute acids; Ag, Hg′, and Pb salts, however, yield insoluble chlorides with HCl, and many salts readily soluble in water are insoluble in concentrated acids, *e.g.*, $AgNO_3$ in HNO_3, $BaCl_2$ in HCl.

Name of Salt.	Soluble in Water.	Sol. in, or decomposed by, HCl or HNO_3.	Insol. in acids.
Acetates	All sol. except some basic acetates (Ag and Hg′ difficultly.)	Basic acetates.	
Arsenates and Arsenites	Of alkalis, and acid arsenates of Ba, Sr, Ca.	Nearly all, (Sb arsenate slightly) Ag, Pb, Hg′ decomposed.	
Benzoates	Of alkalis, Ba, Sr, Ca, Mg, Mn″, Zn, Fe″.	Nearly all.	
Borates	Of alkalis. Many others are slightly sol.	All.	
Bromides	Of alkalis, Ba, Sr, Ca, Mg, Al, Zn, Mn, Ni, Co, Fe, Hg″, Cu″, Cd, Au, Pt (Pb slightly).	Bi, Sb, Pb, Cu′, and $HgBr_2$ in dil. HCl.	AgBr, HgBr.
Carbonates	Of alkalis.	All decomposed. Native $FeCO_3$, $MgCO_3$, and $MgCa(CO_3)_2$, slowly.	

Name of Salt.	Soluble in Water.	Sol. in, or decomposed by, HCl or HNO_3.	Insol. in acids.
Chlorides	Of alkalis and of all metals except Ag, Hg′ Cu′, Au′, Pt″; $PbCl_2$ sol. in boiling water.		AgCl, HgCl. 2 soluble in ho conc. HNO_3
Chlorates	All sol.		
Chromates	Of alkalis, Sr, Ca, Mg, Zn, Mn, Fe‴, Hg″, Cu.	Nearly all.	Ignited $PbCrO_4$ Native Cr iron.
Citrates	Of alkalis, Mg, Al (mono), Cr, Cu, (Ba), Pb (di), Ca (tri), (Zn, Ni, Co, Fe slightly).	All.	
Cyanides	Of alkalis, Sr, Ca, Mg, Hg″, Au, Pt, (Ba slightly).	Fe″ in hot conc. HCl. Single cyanides; AgCN in aqua regia.	
Ferrocyanides	Of alkalis, (Ba, Sr, Ca, Mg, Bi, slightly).	Cd, Mn, in HCl; most others in aqua regia.	Both ferro- and ferri- cyanides are decomposed by boiling with KOH
Ferricyanides	Of alkalis (Ca, Mg, Fe‴, Pb, slightly).		
Fluorides	Of alkalis, Cr, Ag, Pt, Hg″.	Nearly all. BaF_2 sol. in HNO_3	Fluorspar decomposed by H_2SO_4.
Fluosilicates	Of alkalis, K and Ba only slightly, Al, Cd, Cr, Ni, Co, Fe, Pb, Mg, Mn, Sn, Hg, Ag, Zn.	Of Ca, Ba.	
Formates	Nearly all sol., Sn″ insol. Pb sol. in boiling water.		
Hydroxides	Of alkalis, (Ba, Sr, Ca, sl. sol.).	Nearly all.	
Hypochlorites	All sol.	Ag. hypochlorite decomposed into chlorate and insol. chloride.	
Iodides	Of alkalis (Pb slightly).	HgI slowly on boiling.	Ag, Cu′, Hg′, Pb, Pt″, (HgI sol. in KI).
Nitrates	All except the basic nitrates.	Basic nitrates.	
Nitrites	All sol. (Ag slightly), most basic nitrites insol.		

Name of Salt.	Soluble in Water.	Sol. in, or decomposed by, HCl or HNO_3.	Insol. in Acids.
Oxalates	Of alkalis, Cr, Sn^{iv}, Pt, (Mn slightly).	All sol. in HCl.	
Oxides	Of alkalis, Ba, Sr, (Ca, As, slightly).	SnO_2 and ignited Fe_2O_3 slightly. Ag, Pb, Hg sol. in HNO_3. Pb_3O_4 decomposed.	Sb_2O_4, SnO_2, Al_2O_3 and Cr_2O_3 after strong heating
Phosphates (Ortho)	Of alkalis.	All sol. in HNO_3.	
Silicates	Of alkalis.	Most silicates are decomposed with separation of $Si(OH)_4$.	Many native silicates insol. All are decomposed by HF.
Succinates	Of alkalis and most others, (Ba, Sr, Ca, Al, Zn, Co, Fe″, slightly).	Ag, Hg, Pb, Cu, Fe‴, Sn.	
Sulphates	Most sulphates, except Ba, Sr, Ca, Pb, and a few basic ones (Ag_2SO_4 sl. sol.)	Ca slightly. Basic sulphates of Hg, Fe‴, Bi, Sn″ sol. in HCl.	Ba, Ca, Pb, Sr, and anhydrous Cr sulphates.
Sulphides	Of alkalis, Ba, Sr, (Ca, Mg, sl.).	Most are decomposed. Ag, As, Bi, Cu, Pb are sol. in HNO_3; Co, Hg′, Hg″, Ni, req. aq. regia	
Sulphites	Of alkalis, (Ba, Sr, Ca, acid sulphites).	All others decomposed.	
Tartrates	Of alkalis only.	All sol. in acids.	
Thiocyanates	Of alkalis, Ba, Sr, Ca, Fe.	Bi, Cu, Hg″ (Hg′ sl. in conc. acid, AgCNS sol. in conc. HNO_3).	
Thiosulphates	Of alkalis, Ca, Sr, (Pb, Ag, Ba, slightly).	All decomposed.	

REAGENTS FOR QUALITATIVE ANALYSIS.

All the solutions are equivalent solutions except where otherwise stated, and most of them are prepared by dissolving a gramme-equivalent of the reagent in one litre of water.

Name.	Formula.	Equivalent or gms. per litre.	Preparation of Solutions.	Strength.
Acetic acid	$HC_2H_3O_2$	59·58	Glacial acetic acid.	17·7E
,, ,,	,,		Diss. 294 c.c. of glacial acetic acid in 1 litre of of aq.	E
Citric acid	$H_3C_6H_5O_7$	190·62	350 grams.	5E
,, ,,	,,		Diss. 70 gms. in 1 litre.	E
Hydrochloric acid	HCl	36·18	Sp. gr. 1·161.	10E
,, ,,	,,		Sp. gr. 1·084.	5E
,, ,,	,,		Dilute 200 c.c. of 5E to 1 litre.	E
Hydrofluoric acid	HF	19·9	Sp. gr. 1·15.	12·9E
Nitric acid	HNO_3	62·57	Sp. gr. 1·5 at 15·5° C.	23E
,, ,,	,,		Sp. gr. 1·42. ,,	16E
,, ,,	,,		Sp. gr. 1·1656. ,,	5E
,, ,,	,,		Dilute 200 c.c. of 5E to 1 litre.	E
,, ,,	,,			
Oxalic acid	$H_2C_2O_4$	44·67	Diss. 94·5 grams. of $H_2C_2O_4, 2H_2O$ in 1 litre.	$\frac{3}{2}$E
Sulphuric acid	H_2SO_4	48·67	Sp. gr. 1.8427 at 15·5 °C	36E
,, ,,	,,		Sp. gr. 1·1527.	5E
,, ,,	,,		Dilute 200 c.c. of 5E to 1 litre.	E
Sulphurous acid	H_2SO_3	40·73	Saturated sol. in aq.	3·7E
,, ,,	,,		Dilute 270 c.c. to 1 litre.	E
Tartaric acid	$H_2C_4H_4O_6$	74·46	Diss. 375gms. in 1 litre.	5E
			,, 75 ,, ,,	E
Tannic acid	$C_{14}H_{10}O_9$		Diss 10 gms. in 100 c.c. of aq.	
Bromine	Br	79·36	Br. sp. gr. 2.96.	37E
Bromine water	Br, aq.		Saturated sol. in aq.	$\frac{1}{2}$E
Chlorine ,,	Cl, aq.	35·18	Saturated sol. ,,	$\frac{1}{5}$E
Hydrogen peroxide	H_2O_2	16·88	10 vol. sol. ,,	1·8E
Hydrogen sulphide	SH_2	16·91	Saturated sol. ,,	$\frac{1}{4}$E

Name.	Formula.	Equivalent or gms. per litre.	Preparation of Solutions.	Strength.
Ammonium acetate	$(NH_4)C_2H_3O_2$	76·51	Neutralize 60 c.c. of glacial acetic acid with NH_4OH and dilute to 1 litre.	E
,, carbonate	$(NH_4)_2CO_3$	47·70	40 gms. of am. sesqui carb. and 16 c.c. of NH_4OH (·880) diluted to 1 litre.	E
,, chloride	NH_4Cl	53·11	53 gms. NH_4Cl in 1 litre aq.	E
,, hydroxide	NH_4OH	34·81	Sp. gr ·880°	19·7E
,, ,,			Dil. ·880 to sp. gr. ·9643.	5E
,, ,,			200 c.c. of 5E, diluted to 1 litre.	E
,, oxalate	$(NH_4)_2C_2O_4$	30·8	42·6 gms. $(NH_4)_2C_2O_4$, $2H_2O$ in 1 litre.	$\frac{3}{5}$E
,, sulphate	$(NH_4)_2SO_4$	65·60	65·6 gms. in 1 litre of aq.	E
,, sulphide	$(NH_4)_2S$	33·84	Saturate 600 c.c. of E NH_4OH with SH_2 and add 400 c.c. of E. NH_4OH.	5E
Barium chloride	$BaCl_2$	103·38	122 gms. $BaCl_2,2H_2O$ in 1 litre aq.	E
Calcium ,,	$CaCl_2$	55·08	109·5 gms. $CaCl_2,6H_2O$	E
,, hydroxide	$Ca(OH)_2$	36·78	A saturated solution = 1 in 600 aq.	
,, sulphate	$CaSO_4$	67·57	Saturated sol.	$\frac{1}{30}$E
Copper sulphate	$CuSO_4$	79·22	124·75gms. $CuSO_4,5H_2O$ in 1 litre.	E
Ferrous sulphate	$FeSO_4$	75.42	139 gms. $FeSO_4.7H_2O$.	E
Ferric chloride	$FeCl_3$	53·68	18.67 gms. of Fe as Fe_2O_3 in 200 c.c. of 5E HCl and dil. to 1 litre.	E
			For neutral $FeCl_3$ add Na_2CO_3 to the $FeCl_3$ sol. until a ppt. just forms and then filter.	
Gold chloride	$AuCl_3$	100·41	Dissolve 62·5 gms. Au in aqua regia, evaporate excess of acid and dilute to 1 litre.	E

Name.	Formula.	Equivalent or gms. per litre.	Preparation of Solutions.	Strength.
Lead acetate	$Pb2C_2H_3O_2$	161·25	189·5 gms. $Pb2C_2H_3O_2$, $3H_2O$.	E
Magnesium sulphate	$MgSO_4$	59·75	123·5gms. $MgSO_4,7H_3O$.	E
Magnesia mixture			68 gms. $MgCl_2,6H_2O$ in 500 c.c. aq., add 165 gms. NH_4Cl and 300 c.c. of E NH_4OH sol. and dilute to 1 litre.	
Mercurous nitrate	$HgNO_3$	260·07	56 gms. of $HgNO_3,H_2O$ dissolved in 40 c.c. 5E HNO_3 and diluted to 1 litre; add a little Hg.	$\frac{1}{5}$E
Mercuric chloride	$HgCl_2$	134·43	53·7 gms. $HgCl_2$	$\frac{2}{5}$E
Platinum "	$PtCl_4$	83·50	155·86 gms. H_2PtCl_6 in 1 litre aq.	E
Potassium bichromate	$K_2Cr_2O_7$	146·14	146 gms. in 1 litre aq.	E
Potassium chromate	K_2CrO_4	96·47	96·5 gms. in 1 litre.	E
Potassium cyanide	KCy	64·70	65 gms.	E
Potassium ferrocyanide	K_4FeCy_6	91·49	105·5gms $K_4FeCy_6,3H_2O$	E
Potassium ferricyanide	K_3FeCy_6	109·4	109·5 gms.	E
Potassium hydroxide	KOH	55·74	280 gms.	5E
Potassium iodide	KI	164·76	165 gms.	5E
Potassium nitrite	KNO_2	84·55	84·5 gms.	E
Potassium thiocyanate	KCyS	96·53	97 gms. in 1 litre.	E
Silver nitrate	$AgNO_3$	168·69	68·5 gms.	E
Sodium acetate	$NaC_2H_3O_2$	81·46	540 gms. $NaC_2H_3O_23H_2O$ in 1 litre.	4E
Sodium acetate and acetic acid	$Na\overline{A} + H\overline{A}$		250 c.c. 4E Na acetate and 200 c.c. 17E acetic acid diluted to 1 litre.	E
Sodium carbonate	Na_2CO_3	52·65	52 gms. (anhydrous).	
Sodium hydroxide	NaOH	39·76	200 gms.	5E
Sodium hypochlorite	NaClO	73.94		

Name.	Formula.	Equivalent or gms. per litre.	Preparation of Solutions.	Strength.
Sodium nitroferri-cyanide	$Na_2FeNOCy_5$			
Sodium phosphate	Na_2HPO_4	47·05	119·3 gms. Na_2HPO_4, $12H_2O$ in 1 litre.	E
Sodium sulphate	Na_2SO_4	70·55	160 gms. $Na_2SO_4 10H_2O$ in 1 litre.	E
Sodium thiosulphate	$Na_2S_2O_8$	78·53	124 gms. $Na_2S_2O_3, 5H_2O$.	E
Stannous chloride	$SnCl_2$	94·23	Diss. 112·5 gms. $SnCl_2$, $2H_2O$ in 200 c.c. of 5E HCl, dilute to 1 litre; add a little tin.	E
Strontium sulphate	$SrSO_4$	91·14	Saturated solution.	$\frac{1}{100}$E

SPECIAL REAGENTS.

Erdmann's reagent	Six drops conc. HNO_3 in 100 c.c. of water added to 240 c.c. of conc. H_2SO_4.
Fehling's solution	6·9 gms. $CuSO_4$ in 30 c.c. of water, 1 drop H_2SO_4, add 35 gms. Rochelle salt and 10 gms. NaOH in 50 c.c. water, make up to 100 c.c.
Froehde's reagent	Diss. 1 gm. am. molybdate in 100 c.c. conc. H_2SO_4.
Iodine in KI	Diss. 1 gm. I and 2 gm. KI in 50 c.c. water.
Mandelin's reagent	Warm ·5 gm. vanadium chloride or oxide with 100 c.c. conc. H_2SO_4.
Mayer's reagent	13·5 gms. $HgCl_2$ and 50 gms. KI in 940 c.c. of water.
Nessler's reagent	(1) 3·5 gms. KI in 10 c.c. H_2O; (2) 1·6 gms. $HgCl_2$ in 30 c.c. H_2O; (3) 3 gms. KOH in 60 c.c. H_2O. Pour (2) into (1) slowly, then add (3).
Phenolphthalein	1 gm. phenolphthalein in 50 c.c. spirit, make up to 200 c.c. with water.
Schiff's reagent	To a pale sol. of fuchsine in water add SO_2 until decolourized.
Ammonium molybdate	Diss. 10 gms. of the salt in 40 c.c. of 5E NH_4OH, pour slowly into 120 c.c. conc. HNO_3, cool the solution; decant for use after settling some hours.
Cuprous chloride solution	Digest $CuCl_2$ with metallic Cu and HCl.

Indigo solution	Mix together 1 part of indigo powder and 4 of conc. H_2SO_4; allow to stand a few days, then pour into 20 parts of water.
Litmus solution	Digest 10 gms. of powder with 250 c.c. of warm water for a few hours, decant the clear sol., add a few drops HNO_3 until a distinct purple colour is obtained.
Litmus paper	Soak strips of porous paper in the above solution.
Turmeric paper	1 part turmeric root (powdered) digested in 6 of alcohol and filtered. Soak strips of porous paper in this solution.

DRY REAGENTS.

Borax	$Na_2B_4O_7, 10H_2O$. Fused : $Na_2B_4O_7$.
Calcium carbonate	$CaCO_3$. Use Iceland spar.
Fusion mixture	10 gms. Na_2CO_3 and 13 gms. K_2CO_3.
Microcosmic salt	$Na(NH_4)HPO_4.4H_2O$.
Soda-lime	Shake CaO with NaOH sol. and dry.

INTERNATIONAL ATOMIC WEIGHTS.

		H = 1.	O = 16.			H = 1.	O = 16.
Aluminium ...	Al	26·9	27·1	Copper	Cu	63·1	63·6
Antimony ...	Sb	119·3	120·2	Erbium	E	164·8	166
Argon	A	39·6	39·9	Fluorine	F	18·9	19
Arsenic	As	74·4	75·0	Gadolinium ...	Gd	155	156
Barium	Ba	136·4	137·4	Gallium	Ga	69·5	70
Bismuth	Bi	206·9	208·5	Germanium ...	Ge	71·9	72·5
Boron	B	10·9	11	Glucinum (Beryllium)	Gl	9·03	9·1
Bromine	Br	79·36	79·96	Gold	Au	195·7	197·2
Cadmium... ...	Cd	111·6	112·4	Helium	He	4	4
Cæsium	Cs	132	133	Hydrogen ...	H	1·000	1·008
Calcium	Ca	39·8	40·1	Indium	In	113·1	114
Carbon	C	11·91	12.00	Iodine	I	125·90	126·85
Cerium	Ce	139	140	Iridium	Ir	191·5	193·0
Chlorine	Cl	35·18	35·45	Iron	Fe	55·5	55·9
Chromium ...	Cr	51·7	52·1	Krypton	K	81·2	81·8
Cobalt	Co	58·56	59·0	Lanthanum ...	La	137·9	138·9
Columbium (Niobium)	Cb	93·3	94	Lead	Pb	205·35	206·9

		H = 1	O = 16.
Lithium ...	... Li	6·98	7·03
Magnesium	... Mg	24·18	24.36
Manganese	... Mn	54·6	55·0
Mercury ...	... Hg	198·5	200·0
Molybdenum	. . Mo	95·3	96·0
Neodymium	... Ne	142·5	143·6
Neon... ...	...	19·9	20
Nickel ...	... Ni	58·3	58·7
Nitrogen ...	... N	13·93	14·04
Osmium ...	... Os	189·6	191
Oxygen ...	... O	15·88	16·00
Palladium	... Pd	105·7	106·5
Phosphorus	... P	30·77	31·0
Platinum ...	... Pt	193·3	194·8
Potassium	. . K	38·86	39·15
Praseodymium...	Pr	139·4	140·5
Radium ...	... Ra	223·3	225
Rhodium ...	... Rh	102·2	103·0
Rubidium...	... Rb	84·8	85·4
Ruthenium	... Ru	100·9	101·7
Samarium	... Sm	148·9	150
Scandium...	... Sc	43·8	44·1
Selenium...	... Se	78·6	79·2
Silicon ...	... Si	28·2	28·4
Silver ...	... Ag	107·12	107·93
Sodium ...	... Na	22·88	23·05
Strontium	... Sr	86·94	87·6
Sulphur ...	... S	31·83	32·06
Tantalum...	... Ta	181·6	183
Tellurium	... Te	126·6	127·6
Terbium ...	... Tb	158·8	160
Thallium ...	... Tl	202·6	204·1
Thorium ...	... Th	230·8	232·5
Thulium ...	... Tm	169·7	171
Tin	... Sn	118·1	119·0
Titanium ...	... Ti	47·7	48·1
Tungsten ...	... W	182·6	184·0
Uranium ...	... U	236·7	238·5
Vanadium	... V	50·8	51·2
Xenon ...	... X	127	128
Ytterbium	... Yb	171·7	173·0
Yttrium ...	... Yt	88·3	89·0
Zinc	... Zn	64·9	65·4
Zirconium	... Zr	89·9	90·6

WEIGHTS AND MEASURES.

The unit of length is 1 metre = 39·37079 inches, or 3·2809 feet, or 1·0936 yards.

The unit of volume is 1 litre = ·1 × ·1 × ·1 metre, *i.e.*, 1 cubic decimetre.

The unit of weight is 1 gramme = wt. of 1 cubic centimetre (·01 m.) of water at 3·9° C. = 15·4325 troy grains.

Multiples of the above—Kilo = 1000. Hecto = 100. Deka = 10.

Fractions of the above—Deci = 0·1. Centi = 0·01. Milli = ·001.

MEASURES OF LENGTH.

1 micron (μ) = ·001 m.m. = ·00003937 or roughly 1/25000 inch.

1 m.m. = ·03937 inch.

1 centimetre, c.m. = 10 m.m. = ·394 inch.

1 metre = 1000 m.m. = 39·371 inches = 3·2809 feet.

1 kilometre = 1000 metres = 1093·6 yards = ·621 Eng. mile.

1 inch = 25·400 m.m.

1 inch = 2·54 c.m.

1 foot = ·3048 metre.

1 yard = ·9141 metre.

1 Eng. mile = 1·610 kilometres.

WEIGHTS.

1 gram = 15·432 grains = ·035 oz. avoir. = ·032 oz. troy.

1 kilogramme or "kilo" = 1000 gms. = 2·2046 lbs., or $2\frac{1}{5}$ lbs. avoir. (approximately).

Metric ton or 1000 kilos = 2204·62 lbs. avoir.

1 grain = ·065 gram.

1 oz. avoir. = 28·349 grams.

1 oz. troy = 480 grs. = 31·1035 grams.

1 lb. troy = 373·24 grams.

1 lb. avoir. = 453·584 grams.

1 cwt. = 50·0802 kilos.

VOLUMES.

1 litre = 1000 c.c. = 61·027 cubic inches = 1·760 or 1¾ pints, or ·220 gallon or 35·22 fluid ozs.

1 fluid oz. = 28·349 c.c. 1 pint = ·5679 litre. 1 gall. = 4·54346 litres.

1 cubic inch = 16·39 c.c. 1 cubic foot = 28·31531 litres.

NOTES.

To convert grams to grains = Log. grams + 1·18843 = log. grains.

To convert grains into grams = log. grains + 2·81157 = log. grams.

To convert Fah. degrees to centigrade. $\frac{5}{9}(F^\circ - 32)$.

To convert Cent. degrees to Fah. ($\frac{9}{5}$ °C) + 32, or multiply the °C by 2, subtract $\frac{1}{10}$ and add 32, *e.g.*, $16{\cdot}2 \times 2 - 3{\cdot}24 + 32 = 61{\cdot}26$ °F.

1 litre of dry H. at 0°C. and 760 m.m. (or Crith) = ·0896 gram.

1 litre of dry air at 0°C and 760 m.m. pressure = 1·2987 or 1·3 grams.

1 gram of H at 0°C and 760 m.m. pressure = 11·16 litres.

Sp. gr. of air = 14·43. H. = 1.

Coefficient of expansion for gases = $\frac{1}{273}$ or 0·003665.

Parts per 100,000 = grains per gall. ÷ 0·7

Grains per gall. = grams per litre × 70.

FORMULÆ OF REAGENTS.

$AgNO_3$	...	Silver nitrate.
As_2O_3	...	Arsenious oxide.
$AuCl_3$	...	Gold chloride.
$BaCl_2$	...	Barium chloride.
$BaCO_3$	...	Barium carbonate.
$Ba(OH)_2$	...	Barium hydroxide.
Br aq.	...	Bromine water.
$CaCl_2$	...	Calcium chloride.
CaF_2	...	Calcium fluoride.
$Ca(OH)_2$	...	Calcium hydroxide.
$Ca_3(PO_4)_2$	...	Calcium phosphate.
$CaSO_4$	...	Calcium sulphate.
$CHCl_3$	...	Chloroform.
CO_2	...	Carbon dioxide.
CS_2	...	Carbon bisulphide.
Cl aq.	...	Chlorine water.
$Co2NO_3$	...	Cobalt nitrate.
CuO	...	Cupric oxide.
$Cu(OH)_2$	...	Cupric hydroxide.
$CuSO_4$	...	Cupric sulphate.
$FeCl_3$	...	Ferric chloride.
$FeSO_4$	...	Ferrous sulphate.
$H_2C_4H_4O_6$	...	Tartaric acid.
$H_2C_2O_4$	...	Oxalic acid.
HCl	...	Hydrochloric acid.
HF	...	Hydrofluoric acid.
HNO_3	...	Nitric acid.
H_2PtCl_6	...	Chloroplatinic acid.
H_2SO_3	...	Sulphurous acid.
H_2SO_4	...	Sulphuric acid.
H_2O_2	...	Hydrogen dioxide (hydroxyl).
$HgCl_2$	...	Mercuric chloride.
$HgCy_2$	...	Mercuric cyanide.
$Hg2NO_3$	...	Mercuric nitrate.
$HgNO_3$	...	Mercurous nitrate.
KBr	...	Potassium bromide.
KBrO	...	,, hypobromite.
KCl	...	,, chloride.
KClO	...	,, hypochlorite.
$KClO_3$	...	,, chlorate.
K_2CO_3	...	,, carbonate.
K_2CrO_4	...	,, chromate.
$K_2Cr_2O_7$	...	,, bichromate.
KCy (KCN)..		Potassium cyanide.
KCNS	...	,, thiocyanate.
$KHSO_4$	...	,, bisulphate.
K_4FeCy_6	...	,, ferrocyanide.
K_3FeCy_6	...	,, ferricyanide.
KI	...	,, iodide.
$KMnO_4$	...	,, permanganate.
KNO_2	...	,, nitrite.
KNO_3	...	,, nitrate.
KOH	...	,, hydroxide.
$MgCl_2$	...	Magnesium chloride.
$MgSO_4$	...	Magnesium sulphate.
MnO_2	...	Manganese dioxide.
$MnSO_4$	...	Manganese sulphate.
Na_3AsO_3	...	Sodium arsenite.
Na_3AsO_4	...	,, arsenate.
NaClO	...	,, hypochlorite.
Na_2CO_3	...	,, carbonate.
$Na_2FeNOCy_5$		,, nitroprusside.
$NaHCO_3$	...	,, bicarbonate.
Na_2HPO_4	...	,, phosphate.
$NaHSO_3$	...	,, bisulphite.
$NaNO_2$	...	,, nitrite.
NaOH	...	,, hydroxide.
Na_2S	..	,, sulphide.
Na_2SO_3	...	,, sulphite.
$Na_2S_2O_3$	...	,, thiosulphate.
NH_4Cl	...	Ammonium chloride.
$(NH_4)_2C_2O_4$	...	,, oxalate.
$(NH_4)_2CO_3$	...	,, carbonate.
$(NH_4)_2MoO_4$	..	,, molybdate.
NH_4OH	...	,, hydroxide.
$(NH_4)_3PO_4$	...	,, phosphate.
NH_4SH	...	,, hydrosulphide.
$NiSO_4$	...	Nickel sulphate.

$Pb2C_2H_3O_2$	Lead acetate.	SO_2	... Sulphur dioxide.
$Pb2NO_3$	... Lead nitrate.	$SbCl_3$	... Antimony trichloride.
PbS	... Lead sulphide.	$SnCl_2$	... Stannous chloride.
$PtCl_4$	... Platinum tetrachloride.	$SrCl_2$	... Strontium chloride.
SH_2	... Hydrogen sulphide.	$ZnCl_2$	... Zinc chloride.

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